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# **eLmL 2020**

The Twelfth International Conference on Mobile, Hybrid, and On-line Learning

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November 21 – 25, 2020

Valencia, Spain

## **eLmL 2020 Editors**

Alexander Mikroyannidis, The Open University, UK

Maiga Chang, Athabasca University, Canada

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# **eLmL 2020**

## **Forward**

The Twelfth International Conference on Mobile, Hybrid, and On-line Learning (eLmL 2020), focused on the latest trends in e-learning and also on the latest IT technology alternatives that are poised to become mainstream strategies in the near future and will influence the e-learning environment.

eLearning refers to on-line learning delivered over the World Wide Web via the public Internet or the private, corporate intranet. The goal of the eLmL 2020 conference was to provide an overview of technologies, approaches, and trends that are happening right now. The constraints of e-learning are diminishing and options are increasing as the Web becomes increasingly easy to use and the technology becomes better and less expensive.

eLmL 2020 provided a forum where researchers were able to present recent research results and new research problems and directions related to them. The topics covered aspects related to tools and platforms, on-line learning, mobile learning, and hybrid learning.

We take this opportunity to thank all the members of the eLmL 2020 Technical Program Committee as well as the numerous reviewers. The creation of such a broad and high-quality conference program would not have been possible without their involvement. We also kindly thank all the authors who dedicated much of their time and efforts to contribute to the eLmL 2020. We truly believe that, thanks to all these efforts, the final conference program consists of top quality contributions.

This event could also not have been a reality without the support of many individuals, organizations, and sponsors. We are grateful to the members of the eLmL 2020 organizing committee for their help in handling the logistics and for their work to make this professional meeting a success.

We hope that eLmL 2020 was a successful international forum for the exchange of ideas and results between academia and industry and for the promotion of progress in eLearning research.

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# Mobile Application for University Courses of Journalism and Research

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**Abstract**—One of the most common activities of university students in the areas of journalism and communication is to write news or research articles for their classes. To do this, students apply the concepts they studied in their courses to do fieldwork, conduct research, and to write the news. To facilitate this academic activity, we developed the InContext mobile application (app), which contains preloaded templates to guide the student through the process of news writing and research reporting. This application allows a student to add audio, video files, photos and link this to the information. The first stage of our research was for diagnostic purposes. It consisted of a review of the reports and textual articles prepared by students to identify the necessary characteristics that should be considered for the templates we were designing. The second stage consisted of the development of the application and its testing to get feedback and make necessary adjustments to the app. The results so far indicate that, with the teacher's guidance, students follow the required structure of the template, but elements of formatting that could be predicted with the use of the app escape them. Ideally, the app will allow the student to focus on the quality of the content. The future evolution of the app envisages redesigning it to include activities that promote the development of cognitive skills through the use of the app.

**Keywords** - *higher education; educational research; mobile applications; journalism; educational innovation.*

## I. INTRODUCTION

Educational institutions are responsible for providing their students with the tools and skills that give them the competencies they need to be future professionals in journalism and communication [1]. The students have to be able to work with state-of-art technology, inform society, and know how to request and obtain information. Similarly, professionals in creative industries must be able to respond to media outlet demands. Changes in how information is received and disseminated have created a new need: universities must update the courses offered to students in curricula where communication is an integral part of their studies. The variations in training are a result of different trends in how people read and consume information. Nowadays, the use of portable devices such as tablets, mobile phones, and laptops allows access to online journals and magazines. In Mexico, there are 79.1 million Internet users, and 89% of the connections are through mobile

phones [2]. The use of social media is very high (89%), and there is a high percentage of users (82%) searching for information online [2]. This is why the technology provided by the cell phone can be incorporated into teaching, as young Mexican students use it daily. To bring about change, teachers, when doing course design, must focus their attention on learning experiences in which technology can be integrated into them [3].

This paper presents the results of our study. The work is structured as follows. In section II, we present the theoretical background. Section III provides a description of the methodology employed. Section IV presents the research results, and Section V presents the conclusion of this work.

## II. THEORETICAL BACKGROUND

Heutagogy is self-determined learning, focused on the development of capabilities and capacity of the student. Heutagogy is appropriate to the needs of learners in this century [4].

The theoretical-conceptual perspective of heutagogy recognizes the need to be flexible in learning, in the use of resources, and in the facilitation or guidance that a teacher provides to students. Heutagogy is defined by the idea that the student can design and negotiate his/her own learning. The student determines what is most essential and subsequently arranges his/her reading and evaluation assignments [4].

As an example, the journalism schools of the Auckland University of Technology (AUT) in New Zealand use heutagogy as a teaching method in their social media courses in journalism. This method prepares students through a new style of educating that incorporates dealing with the vast amount of information available on the Internet. In this case, a heutagogic framework provides the flexibility for students to perform their course work using existing technological tools familiar to them [5].

Along these lines, this work proposes the hypothesis that the use of mobile applications is useful in academics to enhance critical thinking [6]. There is evidence in this regard: Reen and Ramnarayan's research with medical students at Manipal University, India, is an example [7]. The authors asked medical students to use social media to work on their projects. They concluded that the heutagogic method allowed their students to generate learning products

and develop critical thinking, so the union of this learning methodology with technology can be considered a key to learning for 21st-century youth [7].

According to Crittenden et al. [8], it is crucial that university students know how to use digital technology such as artificial intelligence, augmented reality, drones, the Internet of Things, robots, virtual reality, and 3D printing, among others. Technology applied in the classroom to theory helps students develop critical thinking and creativity, so they can generate value in the professional arena. The authors add that one of the criticisms of technology has been that it can be distracting; however, distraction is also present in traditional teaching [8].

Today's world is characterized by an abundance of data, shortened decision times, and the elimination of geographical boundaries brought about by information technologies [9]. Foreseeably, communication technologies will remain a permanent part of the continuous connectivity in people's work. [10][11]. For these reasons, educators must guide the creators of future content toward the skills of communication and precision. To that end, we developed a mobile application called *InContext*, which specifically targets those competencies. With *InContext*, students have many features now like standard templates, guides, focus group formats, and the key questions and components needed to write journalistic articles or editorials, among others.

Educators have the advantage of being able to leverage student engagement in the classroom through the use of technology. Making the students co-responsible for learning the topics in class leads to their greater involvement. In our research, we see that this involvement occurs when the student, as a user of our app, can add photographs, audio, and video files to content with a smartphone or tablet at the time of the event. These tools, like Google Drive, facilitate the collection of information.

The objective of this study was to design this mobile app with interactive formats that assist the beginning of the writing process or the beginning of social research. *InContext* lets the student use one of the pre-loaded, interactive multimedia templates that correspond to the different journalistic genres and research designs to generate content suitable for journalism or social research. The target users were students of journalism and communication at Tecnológico de Monterrey, Mexico, during the winter 2018 and spring 2019 semesters.

### III. METHODOLOGY

#### A. Participants

The students who participated in the first two stages were men and women between 18 and 25 years old, with 21 being the average age. They were enrolled in various curricula such as Journalism, Communication, International Relations, Advertising, Political Science, and Psychology. All were taking the courses in research and journalism

between the second and fifth semesters of their professional curricula on the Monterrey campus of Tecnológico de Monterrey. The risks associated with this experiment were minimal because no personal or sensitive information was requested from them during the study.

In the first stage, developed in the winter 2018 semester, 161 written articles prepared by 305 students enrolled in five courses were taken as a reference for analysis. The classes were Quantitative Methods for Social Research, Research Journalism, Digital Journalism, Qualitative Methods Research, Advertising and Comprehensive Marketing. The second stage, in the spring 2019 semester, entailed the design of the application and its use by some of the students (n=141).

The *InContext* mobile application has 4 templates for research courses and 16 templates for journalism courses. It allows the students to enter and format their report information, including surveys, interviews, content analyses, and various things relating to news reports, like chronicles, stories, semblances, etc.

#### B. Procedure

Three stages were established for this investigation. The first was developed during September to December 2018 and aimed to identify the essential characteristics that an investigative report or a journalistic article should have. To do this, we reviewed works written by the students before using the technology. The second stage occurred from February to May 2019, in which different students tested the application and made adjustments, and the results of this stage are reported in this paper. The third stage will use control and experimental groups to check whether the use of the tool by the students promotes autonomous learning and develops the critical thinking in students to focus on the content of the reports and not just their forms or structures.

#### C. Tools

*InContext* is an application of specialized software containing custom-made templates for the primary genres of journalism and the elemental procedures of research methodology. The app guides the student to supply the relevant information for each of the points of the templates. The student adds the required multimedia material and sends the content via email or uploads it to the cloud. The use of the app directs the student to the bare minimum inputs necessary to start writing creative or informative text, and it allows the student to explore new ways to deliver content. Also, the app facilitates flexible learning because users can go at their own pace as they practice journalistic writing and conduct academic research.

Although *InContext* is a mobile-device application made explicitly for university students, future versions could be integrated as a suite in the Tec de Monterrey moodle-based learning platform.

This application is based on Laravel, bootstrap, html5, and progressive application techniques. It can be viewed on

Android, Apple, and Windows mobile devices. The app allows the student to access the summary of their contribution (frontend). The teacher can easily design templates, automatic reviews, assessments, and grading scales (backend).

Students access the app at [app.incontext.mx/login](http://app.incontext.mx/login), register, and then select the preloaded formats. Journalism students find specified templates (various formats for news, report, chronicle, review, semblance, conference, press conference, etc.). Research students find other templates (surveys, interviews, etc.).

Students follow the template, inserting title, author, date, sources, questions and answers, photographs, etc. Upon completion of the template, students generate a PDF file that can be downloaded.

Students enrolled in one of these courses have access to the tool and they select the format needed from 20 options.

Figure 1 shows the *InContext* screen to illustrate how students access the app. Figure 2 shows the dashboard where the students can select the specific template to use, and Figure 3 shows the screens with the survey form as an example. In that form, they find the elements that must be written, such as title and objective, theoretical background, and bibliography, etc. The student can attach photos, videos, audios, and links to the text documents they are preparing, and they can proceed at their own pace. *InContext* allows them to generate a PDF report that can be delivered in print or electronic form to the teacher or anyone.

#### IV. RESULTS

This initial review carried out was qualitative. We compared the research reports and the news stories that students prepared before using the application with the work they did after using it and considered some possible improvements in the tasks. In the case of research reports, better results were observed in two specific respects (Table I), namely, the manifest presence of the research objective and the demographic data of the study participants.

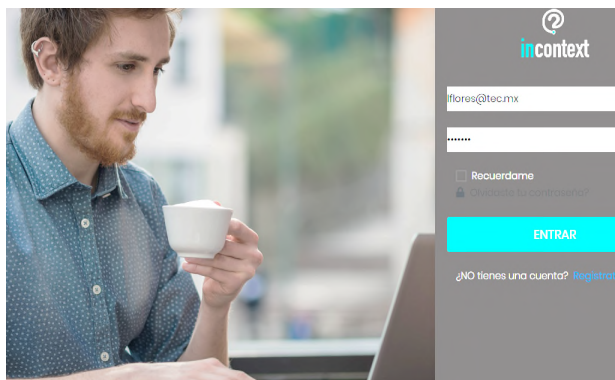


Figure 1. Access screen to the app.

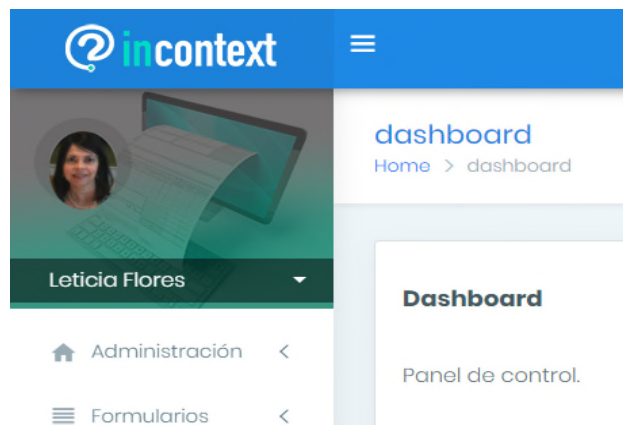


Figure 2. Student access to the dashboard and selection of forms.

In the same way, when reviewing the work of the journalism courses, it was possible to identify improvements with the use of the app (Table II), specifically in the presence of information sources, the news writer credits, and the inclusion of photographs. The application displays the items to be completed in the format, and, therefore, it is difficult to forget or omit their inclusion.

Table I shows the results of the exploratory study using a convenience sample. Please note the low number of students using the app was due to reduced attendance during the days of the study.

#### V. CONCLUSIONS

In the first two stages, the need to design the templates carefully was evident, as well as the usability of the application on both cell phones and computers. However, the most important thing was to identify whether the use of this technology not only facilitates the learning of formats, but also leads to reflection and analysis of the written content. These aspects will be reviewed in the future stage of this investigation.



Figure 3. Example of a template that starts the work.

TABLE I. HITS FOUND IN THE RESEARCH WORK WITHOUT APPLICATION AND USING IT

Research work	Without app	Using app
States the research objective	20/54	5/6
Specifies the demographics of the sample data	26/54	6/6
Total work reviewed:	54	6

TABLE II. HITS FOUND IN THE JOURNALISM EXERCISES WITHOUT APPLICATION AND USING IT

Journalism exercises	Without app	Using app
States the news sources	34/41	37/40
Includes photographs	34/41	36/40
Indicates the writer credit	32/41	40/40
Total work reviewed:	41	40

The results presented in this paper seem to align with those shown by Reen & Ramnarayan [7]; *InContext* facilitates student work by offering them a flexible environment where they can learn better. The results presented in this paper also supports the idea presented by Crittenden et al. [8] that technology is not always a distractor and can be used, instead, as a tool to increase concentration [8]. The results of this paper are encouraging. The research indicates that technology can help students focus; in this project, it offers them the elements to guide the development of writing and communicating using templates. Future work will allow us to test, in an experimental setting, how much these elements facilitate students' work and achievements.

Ideally, with the continuous repetition of exercises, students will incorporate into their knowledge the details of the formats and, on their own, will identify the usefulness of this application. It is hoped that teachers using the app can spend more time reviewing the relevance and the content of student work rather than worrying about the details of form.

The use of this type of technology highlights the importance of continuously updating the education for future

managers. The universities have to offer new educational strategies so that students participate more while they increase their self-efficacy [4]. The future communicators are today's students; therefore, universities have to offer the instructional strategies that are relevant to their future needs.

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# New Learning Method for Structural Understanding in Architecture Based on Gamification

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**Abstract**—One of the challenges architecture students face is understanding static structural and mathematical procedures as part of the structural design concepts they need to apply in their work. This research hypothesizes that gamification and smartphone apps with games using topics of structural design applied to architecture could improve the results in architectural education. Based on gamification and e-learning software, a new learning method was created consisting of six strategies: understanding the target audience, definition of learning objectives, designing the experience, identifying resources, application of gamification elements and recap of the process; the method's importance was found in being the first in its kind at the architecture undergraduate level. To assess the effects of this method, a comparison between two classes (with and without the method) was made. The results obtained were promising: most students gained motivation, engagement, and higher final scores in their structural analysis and design courses.

**Keywords** - *educational innovation; higher education; gamification; architecture; structural design.*

## I. INTRODUCTION

In the field of architecture, physical and mathematical concepts are integral to the structural design process. However, considering the abstract nature of these concepts, architectural students often find it challenging to understand the mathematical simplifications for solving the behavior of structural elements, such as frames, bearing walls, slabs, columns, and many other built-in structures. In the School of Architecture at Tecnológico de Monterrey, Campus Ciudad de México, e-learning is encouraged as a tool for facilitating course objectives. Thus, in the courses of structural design, we first implemented an existing smartphone app, designed by the principal author of this paper exclusively for practicing physical-structural concepts in architectural design [1]. This app is a game-based learning method built on the potential of video games to improve understanding of structural design concepts such as stresses (tension and compression) and flexural moment and their effect over buildings and other structures, such as bridges, following the game elements of mechanics, story, aesthetics, and technology.

The software is designed as a virtual laboratory with practices to help students review the main concepts by a

step-by-step guide to win each game. In the first semester, students were invited to play with this app as an additional learning tool. From a total of 22 students in the two groups of a structural design course, only 13 downloaded the app and played the games, while the others only followed the lab practice to win each level and comply with the assigned task. Even though the content of the application was part of the course syllabus, the students were not analyzing the concepts and were not engaging with the subject.

Therefore, the need for a different learning method to improve student engagement in the structural design course in architecture became clear. We hypothesized that gamification, as a learning method that occurs in a non-game context and focus on students' engagement and challenge [2], could potentially provide better results in the understanding of structural design for architects. Even though recently, gamification has been gaining momentum in education [3], very few studies measure the impact of the teaching process in the educational context and explore methods for improving the program by gamifying the course literature and material from teachers' point of view [4]. Moreover, no studies have been found by the authors that explore the gamification method in the field of architectural education; this is due to most architecture schools' lack of knowledge on gamification and the existence of free applications that can be used in education.

This research aimed to design and measure the impact of a new learning method based on gamification to improve the structural understanding of architectural education from the teachers' point of view. The purpose was to facilitate the learning of abstract physical and mathematical concepts related to structural design for architectural students and improve the overall quality of their architectural proposals. The benefits of such a method can bring in improving architectural education are multiple: from better structurally designed buildings to increasing students' satisfaction and self-confidence.

The work done for the research is based on a specific successful educational experience, but the methodology described could be adapted to other areas using mathematics and physics, such as civil engineering.

In order to understand the development and results of the proposed gamification method and its application, Section II of this paper presents the steps used to create the proposed method; in Section III, the working method and class



experience are presented, while Section IV presents the assessment of the learning method results. Students' feedback and conclusions/future work are presented in Sections V and VI, respectively.

## II. CREATING THE METHOD FOR STRUCTURAL UNDERSTANDING IN ARCHITECTURE

Following the six steps proposed by Hsin et al. [3] for gamification at the Management School at the University of Toronto, we designed a new learning method for structural design understanding in architecture with the following six strategies:

### A. Understanding the target audience and the context

Within the architecture undergraduate program, the Steel Structural Design course is the last of four courses regarding Structural Analysis and Design. In theory, that implies that the students should have already mastered the structural analysis concepts in previous classes, and the students should be capable of immediately applying structural analysis in the course of Structural Design. The first strategy revolves around verifying students' abilities in structural analysis and setting the app tool and course dynamics.

- Strategy:

Architecture students arrive at this course with different levels of understanding of the basic concepts about structural analysis. To accomplish equal student's understanding, the following actions are considered: explaining different kinds of structural solutions, analyzing iconic architectural buildings, and downloading the smartphone app for the course. Most of the students at Tecnológico de Monterrey have a smartphone at hand, so the downloading and checking the app's function is done relatively fast.

### B. Defining learning objectives

Architecture students go through Structural Analysis courses without understanding their real application in designing buildings' structural elements. The second strategy is aimed at defining the learning objectives of the Structural Design course in applying structural analysis concepts to propose correct, new, and/or sustainable architectural solutions.

- Strategy:

Explaining general structural concepts and consequences of using them in architectural solutions.

### C. Structuring the experience

Students need to understand every stage of the structural design process. The third strategy deals with structuring the students' experience hierarchically, from solving smaller to more significant tasks, in order to gradually achieve the course objectives. If students do not understand every stage of the structural design, they will lose interest in the subject.

- Strategy:

Assigning starting exercises focused on smaller tasks to review the main concepts of the pre-courses and gradually increase the difficulty of the tasks to achieve the final

solution of the structural design. As an example, we start in class solving a problem where the relation between the tension stress, the tension load, and the cross-section area of a steel cable are related in order to design a staircase suspended with cables from the ceiling.

### D. Identifying resources

The course followed "Problem Based Learning" (PBL) [5] strategy before introducing gamification. To have a smooth course transition and become acquainted with this new strategy, at the end of every topic, a PBL challenge was introduced as part of an everyday exercise in the classroom.

- Strategy:

Activities from the gamification process were introduced as part of everyday work in the classroom; the first exercise of each theme was developed by writing down each step used to get the right answer. The following tasks are from the app, where scenarios are more real and displayed with the same topics. The students practiced one game per week.

### E. Applying gamification elements

The fifth strategy builds upon the previous experiences in using the app and introduces more complex challenges to deepen the students' understanding of structural design problems. By using the gamification elements introduced in this strategy, the students have an opportunity to conceptualize better structural solutions and improve their course evaluation grade.

- Strategy:

The app selected must include one of the topics of the course and the professor should know how the app works to solve the problem, in order to help students to get the right answer, play the app and win each game.

The student has to solve problems with different levels of complexity and win the game at each level in order to move on to the next level. Every completed practice brings points when finished successfully, and these points were calculated as additional points in the monthly evaluation. Since not all students have the same capacity for solving mathematical problems fast, extra time was assigned to specific individuals to complete the task.



Figure 1. Application use in class 1 for steel design.



They would take the app practice as homework, getting an extended timeframe to finish the task. The course teacher followed up with those students after class by WhatsApp to answer any doubts. We concluded that it is quite important to allow students to work in teams since teamwork discussions encouraged students' confidence in solving problems.

In Figure 1, the app scenario for a compression problem using a parabolic biarticulated arch is presented; the objective is to understand how the structural design is applied over an architectural project as this bridge.

#### F. Recap

Previous strategies were tested within the real course focus groups, adapting the strategies to calibrate and improve the method.

- Strategy:

Adapt the method's strategies to the group's needs and capabilities in order to get the best results in the learning process.

### III. LEARNING EXPERIENCE AT THE CLASSROOM LEVEL

The above-described learning method was applied to three different groups of Structural Design courses in the last three semesters. The courses where the method was applied were "Design of Reinforced Concrete Structures" and "Design of Steel Structures." The main topic of both courses was the structural design of steel or concrete bearing elements, through theoretical explanation of structural behavior and application of building codes equations.

The classes were held twice a week and follow the PBL strategy. The first weekly class was dedicated to an explanation of a theoretical structural analysis approach and a presentation of structural element design on the blackboard with the participation of the students. Since the class time was limited, we focused on solving small problems concerning structural element design.

The second weekly class was dedicated to problem-solving assignments. To evaluate the students' performance, a scenario of a structural problem was presented for students to solve using the concepts learned in class. Since the problems tackled in the class were focused on stand-alone structural elements, students' found it hard to understand the relationship between that single element and the complete structural system. The PBL strategy was found particularly helpful in establishing the relation between theory and real examples with a constructive problem.

To incorporate the gamification method in the first-weekly class concerning the theory of structural analysis, numerical exercises were designed to be solved together with the students on the blackboard. The exercises were based on small real cases of buildings with the same structural solution so that the students can understand the numeric results over real elements; different structural solutions were analyzed as well.

In the second weekly class, the previous exercise was recalled, and the steps to solve the problem were written on the blackboard. Working in teams, the students used the e-learning app to solve the class assignment. The students were instructed first to read and analyze the problem, and after that, to start proposing solutions. Each virtual practice (e-learning software) contained two or three problems, with the level of complexity increasing as students fulfill each task (adaptive strategy); while using the virtual practice, students must choose an Avatar as part of the game mood. The Avatar is important for game-based learning and gamification in order to allow students to feel part of the game, get a new identity that, in some cases, could be more fierce and challenging.

Students were also allowed to work alone; however, the formation of teams with 2 to 4 students was encouraged for better results. At the beginning of the class, the teacher verified that every student in the class understood the problem correctly and helped them to confirm the steps needed to solve the virtual practice.

As each student finished all the tasks (quest) included in the e-learning software, they got two prizes: game points and a virtual tour of the case study structure using augmented reality. The game points could be exchanged for additional monthly grade points (0.25 additional points for each task finished, so at the end of each month, they could get one extra point on their grade). Since some students needed more time to understand and finish the game quest, they could ask for additional time, with a week being the maximum time allowed to finish the task and earn the same amount of points as the other students. The students showed low interest in the virtual tour of the building, where information about the architect and the project was displayed. Students were already acquainted with this kind of virtual experience as they have played games with more sophisticated imagery (i.e., Nintendo or X-Box), so students have not considered the augmented reality as a grand prize.

After the quests were completed, each team presented their conclusions about: i) the game; ii) the theory involved; iii) the architectural project used for the practice. This part was as important as the game itself because it allowed students to process all the information and understand the relationships between theory and practice. As the experience sank in, the students were able to comprehend the process of application of theoretical analysis and design in the real world and to realize the implications structural design has on the quality of the architectural project.

As teachers, we know that the synthesis of learning and acknowledgment is very important for students thus, when a student archived all the learning goals in the one-course theme, he/she was entitled to a badge: structure expert. This badge made students feel recognized and more engaged with the topic. If a student acquired three badges, he/she was eligible for an exemption from the final exam.

The exams for the structural design courses were also designed using a PBL strategy. The new learning method based on gamification helped the students to a) analyze complex scenario problems with a step-by-step approach; b) improve the design thinking process to solve the problem in

stages; and c) gain confidence in their work, therefore leading to better results in the exam evaluations.

#### IV. ASSESSMENT OF THE LEARNING METHOD RESULTS

Even though the introduction of the new learning method based on gamification has been challenging for us as teachers, the students' performance in the class improved. The improvement was observed in the better final evaluation grades that were mostly due to the better exam performance, as well as to the extra grade points acquired during the class activities.

To confirm the effects of the new gamification method on students learning, we compared partial and final grades from a selected previous group that did not use the method (defined by the authors as control group using just PBL) and a group where the gamification method was used during the same course with the same length and number of students (defined by the authors as experimental group using PBL and gamification).

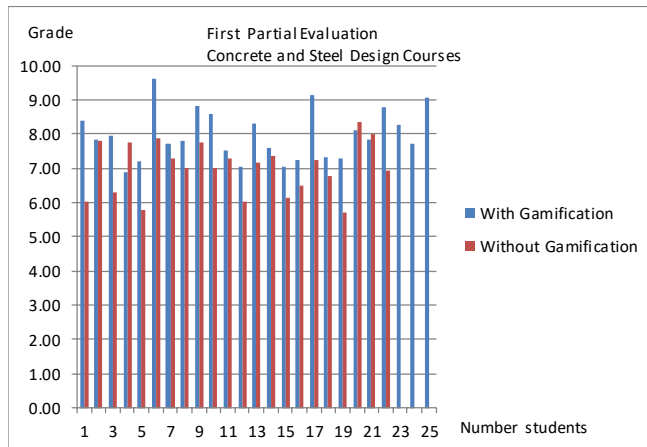


Figure 2. Comparison of group first partial evaluation.

At Tecnológico de Monterrey, the grade evaluation range is from zero to ten, where ten is the highest score, and grade below seven is considered a fail.

In Figure 2, the first partial grades of 52 students were presented. Red lines correspond to students that took the courses without the gamification method, and blue lines are the grades of students that took the same courses with the gamification method. As can be seen from the graph, the grades were relatively higher in the courses with the gamification method. More importantly, there were no grades below seven in the gamification courses. These results are essential for the class, as dropping out from the course is diminished.

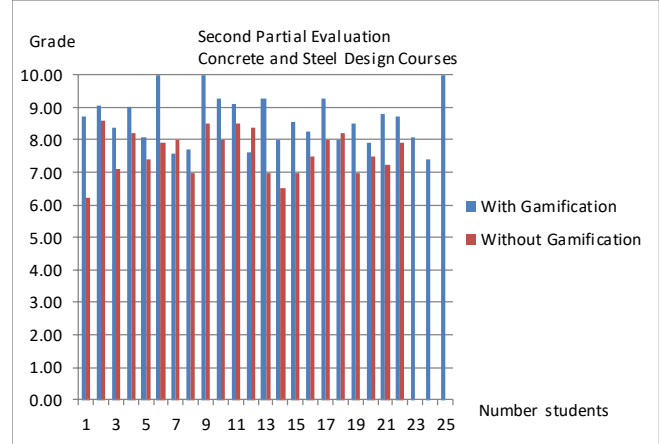


Figure 3. Comparison of group second partial evaluation.

In the second partial evaluation (Figure 3), the students from both courses, with and without the gamification method, had higher grades compared to the first partial evaluation. This behavior could be explained by the fact that as students progress through the course, they get better acquainted and more confident with structural design topics.

In Figure 4, we compared the final exam grades in courses with and without the gamification method. We found a considerable improvement of the average final grade in the courses with the gamification method (average of 8.0), compared to the average grade in the courses using just PBL without gamification (average of 6.8). The increment in the course grades means that students got a better understanding of each topic and its application in real-life problems, like the ones solved in the mobile app.

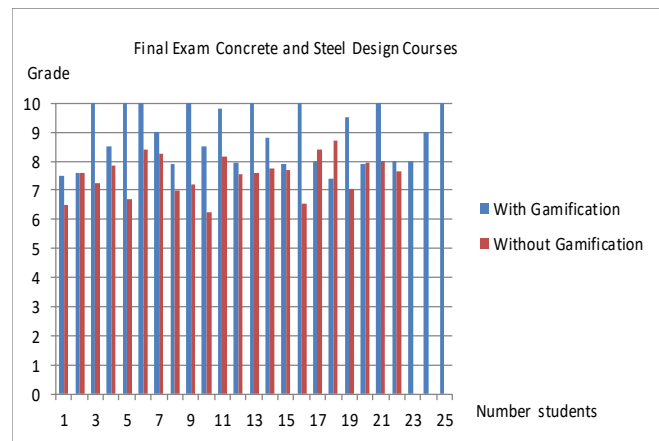


Figure 4. Comparison of final exam grades between courses.

## V. STUDENTS FEEDBACK REGARDING THE NEW METHOD

We designed and conducted a questionnaire to analyze students' feedback regarding the effectiveness of the new learning method based on gamification in the experimental groups. The purpose was to quantitatively assess student personal achievement using the Likert scale [6], ranging from 1 = not at all characteristic of me, to 5 = very characteristic of me. To understand the results in the context of previous courses without the gamification or control group, we conducted the same questionnaire to those groups as well. The mode (statistic) is presented as the evaluation result for each subject.

As presented in Table I, students in the experimental groups were more engaged during the class, asking more questions, and putting more effort into completing the tasks assigned. The experimental groups were also more inclined to using the e-learning software app after class.

TABLE I. EVALUATION OF STUDENTS COURSE ENGAGEMENT QUESTIONNAIRE (SCEQ)

No.	Evaluation		
	<i>Behavior, thoughts, and feelings</i>	<i>Control group</i>	<i>Experimental group</i>
1	Participating in class	3	4
2.	Asking the instructor questions for a better understanding	3	5
3.	Asking the instructor questions to get the application game done	0	3
4	Playing the application game after class	0	3
5.	Putting forth effort	3	4
6.	Desire to learn the material using the application game	1	3
7	Playing the application in teams	0	4
8	Explaining the solution to solve the app quest between companions	0	4

Looking at the answers for questions 7 and 8, and watching their behavior in class, we discovered that teamwork is one of the necessary conditions for better student engagement. The students felt that within a team, they could quickly clarify misunderstandings from the theoretical aspect and achieve faster and better solutions. The teamwork also positively affected the feeling of confidence while working.

We also evaluated the students' satisfaction with the courses based on the new learning method. The scores were again based on a Likert scale in five-point grade, five being the best score (Table II). It was assessed that the students' experience with the course using gamification was overall positive; students were motivated by the prizes and considered the application fun to use, which led to a better understanding of the theory.

TABLE II. EVALUATION OF STUDENTS METHOD PERFORMANCE

No.	Evaluation	
	<i>Phrases</i>	<i>Evaluation</i>
1	Performance of the course	4
2.	The application game helps to understand structural behavior	4
3.	Playing the application in the classroom was challenging but fun	4
4	The application clarifies the theory applied to real cases	4
5.	Getting badges and points is adequate	4

Finally, students were asked to evaluate the course teaching approach of mixing the new learning method for class activities in 70% of the course with a more traditional lecture style for the theoretical part in the rest 30%. To our surprise, students considered interesting the combination of strategies during the course that provided time for playing with the app and standard lecture time. Moreover, most of the students were grateful for the extra time allowed for finishing the tasks, as they could try out different answers while playing that led to a better understanding of the theory.

## VI. CONCLUSIONS AND FUTURE WORK

By analyzing the grade results and students' feedback, we concluded that the students' understanding of structural design was enhanced in the courses that applied the new learning method based on gamification. 90% of students finished all the games assigned in the semester, and 60% got the badge "structure expert", which implies significant improvement in students' engagement compared to previous courses that did not utilize the gamification method. Since the first courses using the new method also included 30% of more traditional lectures, we assume that students' performance could improve even more if the new method is applied more consistently.

One of the most interesting observations was that millennial students do not consider competition as an incentive; they prefer to work at their own pace without pressure and in teams. The preference for teamwork was found in the opportunity to collaborate with more skillful or well-informed students. In fact, students confirmed that giving level awards made them feel uncomfortable, thus in the future, we will only focus on awarding one type of badge to all who complete the game quest.

Time was found to be an important factor in the success of the learning method since less skillful students needed extra time to accomplish their tasks at their own pace. Avatars were found to be slightly significant while playing with the e-software app, however extra points that students acquired for the class activities were found to be incentivizing. Immediate feedback was also appreciated, as

students could quickly adjust their work and search for better solutions without wasting time.

The gamification method proposed is more than game points; it is a strategy where the professor gets more acquainted with the student, giving confidence while learning how to solve real-life problems using today's technology; the virtual environment experimentation to solve real-world challenges offers the students a better understanding about the mathematical solution and its application over real architectural projects. In the real world context where stakes are high and human lives at risk, better-prepared architects with a deeper understanding of structural problems are the goal of education.

With the game-based learning app used, made especially for this courses, students knew immediately when they were making a mistake, and that instant feedback allowed them to progress faster, ultimately providing them with a better understanding of structural design. In Mexico, the gamification method has not been developed; there is a world of free apps that can be used for teaching, but a method is needed in order to achieve each course objective.

Teachers may find the following difficulties using the method proposed for other courses: a) finding the best app for each subject; it should get the results needed to get the students understanding and engagement; b) the app must exist for IOS and Android system so every student can use it; c) time should be programmed in order to give the student the theory, its application and solving the problem while playing with the app.

However, there is still more work to be done to improve the method, mainly to increase students' participation and engagement further. The level of challenges has to be reconsidered carefully since time management is crucial for the success of the method —

professors using apps in class need to know how they work and the theoretical concepts they follow in order to choose the one that fits for the subject of each class and guide the student learning with a specific purpose. Finally, further studies are necessary to enrich the students' educational experience and find ways for better access to teachers' feedback.

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## Creating Free, Interactive Resources to Support Student Success: Pilot Programs and Preliminary Findings

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**Abstract**—The cost of higher education in the United States continues to climb. In addition to tuition prices, textbook prices have soared at alarming rates. In the US state of Georgia, the University System encourages and offers financial incentives to faculty to create their own course resources, including textbooks and ancillary materials. This program is called Affordable Learning Georgia, or ALG. Open Educational Resources, or OERs, have shown to support student success including retention, completion, satisfaction, and learning outcomes. At Kennesaw State University (KSU), faculty members have stepped up to create course materials, ancillary resources, and even student support materials. Early surveys have shown that students have been appreciative of the faculty efforts and have had positive responses to the various components faculty have created and provided. This innovation in the type of resources provided has boosted student satisfaction. In addition, the resource on academic integrity has reduced the amount of cheating through social media.

**Keywords**—Affordable Learning Georgia; OERs; student success; textbooks; United States.

### I. INTRODUCTION

The cost of higher education in the United States continues to climb. One area driving up costs is the constant reduction in each, individual state's contribution to higher education. "Overall state funding for public two- and four-year colleges in the school year ending in 2018 was more than \$7 billion below its 2008 level, after adjusting for inflation" [1]. Students are asked to take on more and more of the cost burden, and they are encouraged to take out student loans to fund their educations. The average student loan debt, per person, in the United States is \$31,172 [2]. An additional catalyst in the soaring prices is textbook publishers. These publishers saw that they had a captive market and took advantage, jacking up prices and churning out new editions every year or two just so they could force students to purchase new editions instead of saving money buying used copies. Textbook costs have soared, rocketing up past four times the rate of inflation between 2006 and 2016 [3]. Also, books are no longer always physical and made of paper. Publishers now "bundle" digital textbooks with unique access requirements that must be purchased new each time. This practice puts a stop to selling back

textbooks and purchasing used, and more affordable, versions [4].

### II. AFFORDABLE LEARNING GEORGIA

Compared to other US states, the state of Georgia contributes more than most to public higher education [5]. At the same time, political leaders still want to assure taxpayers that the state government is keeping prices down and taxes low. To that end, the state ended many endeavors that were funding the purchase of hardware and software for students. This effort returned the financial burden for expensive educational technology and student support software and programs back onto students' pocketbooks.

The state of Georgia's University System, also known as the University System of Georgia, or USG, also set aside small amounts of money to incentivize and compensate faculty and staff to create learning materials for students to replace commercial and publisher materials. This initiative is called Affordable Learning Georgia, or ALG. What this initiative means in reality is if a student needs a license for a software vital to his or her career success, he or she will have to pay for it out of pocket because the school no longer can provide a license. However, more classes are being taught with free textbooks, so textbook expenses are no longer hindering students.

While some faculty balked at this direction, remarking that it is not their job to do extra work to reign in publisher greed, many faculty noted that they had already created such materials and would be happy to get a little one time incentive from the state and recognition to share them. Also, quite a few faculty felt it was the right thing to use their skills to help defray costs for students. As of Spring 2020, 26 Georgia universities had earned ALG grants, benefiting 417,000 students and saving them a total of \$69.19 million [6].

### III. THE MAGIC OF OPEN EDUCATIONAL RESOURCES

#### A. Overview

The author is a faculty member in the state of Georgia who has enjoyed working with digital tools to create online learning experiences that replace commercial and publisher products. In this paper, we will describe the products

created, the purpose of them, and the early student responses. This paper also includes links to the resources mentioned.

### B. Impact in the Classroom

In 2015, the state of Georgia began pushing the use of Open Educational Resources or OERs. The USG established ALG to spread information about the benefits of OERs. Research shows students learn more, get better grades, save money, take more classes, graduate faster and are more satisfied with their experiences when their classes use OERs [7]. These results sound amazing, but they are a logical outcome. If a student starts the semester with the course materials, he or she will not get behind, and, therefore, will perform better. With the savings from not having to purchase the textbook or take on an extra job to pay for the textbook, students can take more classes and devote more time to those classes—thereby, graduating faster and with higher grades.

In fall 2015, we worked with a team of faculty and an instructional designer at KSU. The team received an ALG grant to create an open technical communication textbook, currently titled *Open Technical Communication* [8]. The textbook was piloted in a summer 2016 online course called WRIT 3140: Introduction to Technical Communication. WRIT is a prefix for a group of classes that emphasize writing. The number 3140 refers to the fact that the course is taught at a junior, or upper, level at the university. In this course, students are instructed in the basics of writing for the technical fields, including computer science and engineering. Students in the course were surveyed regarding their experiences with the open educational resource, which in this case was a free, open, online textbook called *Open Technical Communication*. Of the 21 students who responded to the survey regarding the textbook, 95% responded positively. To further evaluate the initial success of the endeavor, we compared the retention rate, average grade, and evaluation average with the same course taught the previous summer with a publisher textbook which cost around \$140. Both courses were taught online. To put this data in clearer context, the retention rate with OER went down. However, the average grade went up. In this class, grades are calculated as failing, or F (earning 0-58% of the points available in the course); D (earning 59-69% of the available points); C or average (earning 70-79% of the available points); B or good (earning 80-89% of the available points); A or excellent (earning 90-100% of the available points). The evaluation in this chart refers to the average score on the instructor's end of course evaluation. It is a measure of student satisfaction. In this case, one can see that the student satisfaction increased in the course with the open educational resources. In the course using OERs, the retention rate was lower, and the grades and course evaluations were slightly higher. Also, "Sum" refers to the fact that the courses being compared were taught in the summer session of the university, which is 8 weeks instead

of the usual 16 weeks in fall and spring. Table I shows the retention data.

TABLE I. RETENTION DATA FROM WRIT 3140 WITHOUT OERs AND PILOT SECTION WITH OERs

Table Showing Comparison of Online WRIT 3140 Course with OER vs. without OER		
	WRIT 3140 Sum 2015 (without OER)	WRIT 3140 Sum 2016 (with OER)
Retention Rate	40/42 (95%)	21/25 (84%)
Average Grade	74 C	78 C
Evaluation	3.56	3.75

### IV. OPEN TECHNICAL COMMUNICATION: THE GATEWAY TEXT

The faculty team created *Open Technical Communication*, the free, online, technical communication textbook, by remixing a previously available, but not yet completed, free, online technical communication textbook created by Dr. David McMurrey. It is entitled *Online Technical Writing* [9]. Dr. McMurrey gave the KSU faculty team permission to use his work in the project. We completed or updated some of the existing chapters, authored original chapters, and added resources such as practice quizzes and supplementary videos. Thus, *Open Technical Communication*, a remix and derivative of *Online Technical Communication*, was born.

In addition to the webpages and examples created by Dr. McMurrey and the faculty team, the remix contains videos, interactive exercises, and assignment ideas to support the use of the text either by teachers and students or persons simply wishing to learn more about technical communication. This textbook continues to be in use at Kennesaw State University and has been adopted for use in a few institutions. It has had 7,946 downloads over the past four years, the majority of which are in the Eastern US. The textbook has been downloaded in 135 countries with the top three users being the United States (3813 downloads), India (644 downloads), and the Philippines (428 downloads). The most downloaded chapter is the one entitled "Ethics in Technical Communication" [10].

We also teach American literature and wanted to use freely available resources in our literature courses, as well. In 2015, the goal was a challenging one to achieve, as the state was encouraging faculty to create their own textbooks.



However, a professor cannot simply write 10 great American novels to use in American literature courses. But, by 2017, the needed resources were becoming available. It was possible to find a great deal of readings on the Internet. And in 2018, two OER literature textbooks were made available. These were *Becoming American: An Exploration of American Literature Precolonial and Post-Revolution* [11] and *Writing the Nation: A Concise Introduction to American Literature 1865 to Present* [12]. Both books are published and maintained by the University of North Georgia Press. With the publication of these works, it was possible for us to make one of our literature courses 100% OER, with the other requiring less than \$5 in course material expenses.

#### A. Moving from Publisher Resources to OERs

There are many research-based, positive reasons to adopt OER. However, OERs are not a panacea. A critic of OERs might argue that OERs do not work for every course. Often, they require vetting, adaptation, and supplementation to work successfully in a course. As was described above regarding the open technical communication textbook, the free book available was not yet completed. The faculty at KSU who wished to use it had to take a semester, create a work schedule, and update and complete it themselves in order to provide the benefits to their students. Many of these reasons are given by faculty and publishers as reasons not to adopt OERs. To counter these arguments, one might consider that publisher textbooks, too, require vetting, adaptation, and often, supplementation. The difference is that once an OER is adopted and revised to suit an instructor, the instructor has control over the content.

#### B. Filling in the Gaps

While the American literature survey OER textbook provided these supplemental materials, such as author biographies, to a degree, we wanted additional support and more context for students. As a subject matter expert, we had the knowledge to share with students to support their learning. Using Articulate Storyline [13], we were able to create several support pieces for the OER American literature textbooks. Topics included Transcendentalism, the Enlightenment, and American Literature after World War II. These support pieces were entitled Read'n Quizzes because they presented very text-heavy slides to students, slide by slide. Periodically, there was a quiz question. Each student had to complete the Read'n Quiz in order to earn 10 points for the activity. The technology allowed the instructor to upload the Read'n Quiz into the Learning Management System (LMS), in this case Desire2Learn BrightSpace, or D2L [14], as a Shareable Content Object Reference Model, or SCORM module so that quiz grade is automatically transferred to the gradebook. SCORM modules are built to a standard that includes four traits: "First, sustainability. Teaching resources will not be invalid because of the update of technology. It can be used for a long time. Second, reusability. Teaching can basically be used without

modification. It can be reused in different platforms, and can be combined with other teaching contents according to their needs. Third, interoperability. Because teaching materials follow a unified standard, it can be presented on any standard platform, or can be modified by editing tools that conform to the standard. Fourth, availability. With the platform, learners can read the learning and teaching resources through the Internet without any time and space constraints, so as to achieve the purpose of distance learning" [15]. Through creating Read'n Quizzes in SCORM format, we were able to create learning objects that can be shared freely and widely. Also, we were able to motivate students to take in the connecting information, something that is normally very boring and students are prone to skip, so that they could gain more context and learn more.

In a fall 2019 survey regarding the student opinions of the OER materials, students were asked their impression of the Read'n Quizzes. On the survey, presented to the course after the midterm exam, students were posed this question: To help support the OER materials, your professor created what she called Read'n Quizzes where you watched presentations that included questions and were counted for a grade. Would you recommend she continue using those materials? Of the nine out of 25 students who answered the question, 44% said they would recommend the instructor to continue using the Read'n Quizzes if they keep the cost of the materials down. Here is a breakdown of the survey results:

44%="Yes, if they keep the cost of materials down."  
 22%="Yes, I found them engaging."  
 22%="No, I had a hard time accessing them."  
 11%="No, it wouldn't record my grade correctly."  
 0%="No, I found them boring."

Figure 1 shows the response breakdown to the question on the survey. As can be seen, 66% of students were willing to

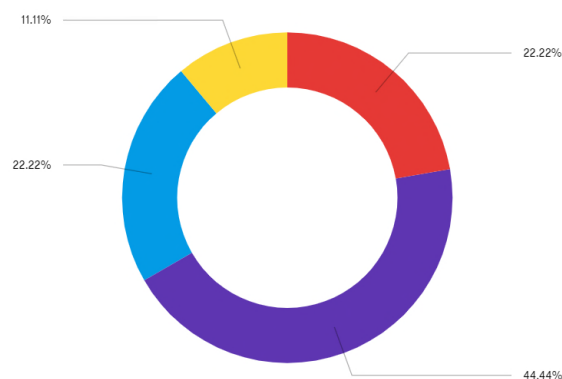


Figure 1. Graphic representation of student perceptions of Read'n Quiz activities.

tolerate the activities/actually liked them, while 33% had a hard time accessing the materials or could not get them to record their grades. The sample is small, but this pilot program shows that technical difficulties, not content, seem to be the deterrent to student approval. The materials are undergoing troubleshooting to improve the student experience.

## V. EXPANDING THE STUDENT SUPPORT RESOURCES

In the face of budget cuts mentioned in the introduction, software and student support programs had to be dropped. One of those was a commercial product that posed a series of questions to students and used analytics to help them to assess their readiness for online courses. It also had additional helpful features that were not available on the “Is Online Right for You?” helpsheets many institutions have on their websites. Those features included reading comprehension assessments, typing instruction, learning style assessments, and other information that was meant to benefit students and also provide instructors with an overview of what strengths and challenges students might be bringing to each class. Without that online readiness tool, many faculty members felt that students were not getting the preparation they needed to be successful in an online course. After all, KSU did not provide online students with any special orientation to ensure they understood what may be asked of them as online students. As this online orientation resource was created, it became clear that there were several additional resources that could help support student success: documentation and social media expectations.

### A. Are You Ready for an Online Course?

To replace the commercial online orientation resource that was no longer affordable to the institution, a team in the College of Humanities and Social Sciences (CHSS) worked together. Using software such as Articulate Storyline, PowerPoint [16], Camtasia [17], and Shutterstock [18], the team created “Are You Ready for an Online Course?” [19]. Figure 2 shows the opening screen of the “Are You Ready for an Online Course” interactive presentation created by KSU faculty and staff to replace costly materials and support student success. This interactive presentation addresses tech-

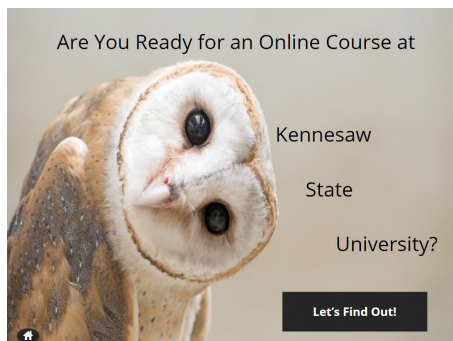


Figure 2. Introductory image for the resource, “Are You Ready for an Online Course?”

nology, communication, time management, goals and motivation, and other skills. It is KSU specific, but certainly any user might find helpful, research-based information there. Two versions are created. One is available on the open web for anyone to link to. A second, zip file is also available for anyone who might like to integrate it into an LMS using SCORM.

### B. Documentation Resources

One of the goals for the student support resources was to find topics that were usable across a wide variety of courses in CHSS. A resource that had been requested for a while was a tutorial or other learning experience that helped students better understand documentation in research-based work, including how to avoid plagiarism.

CHSS courses mainly require Modern Language Association (MLA) and American Psychological Association (APA) documentation styles. Therefore, two documentation activities were created, one for MLA and one for APA. The activity starts with the Goblin Threat game created by Mary Broussard for Lycoming College [20]. Then it moves to the basics of MLA or APA, depending upon the presentation selected by the instructor. Like the online course readiness tool, it also includes a quiz question that can register in the LMS gradebook, should the instructor choose. The APA resource [21] and the MLA resource [22] are freely available.

Of course, this resource cannot replace the instructor’s assignment guidelines or answer every documentation question, but it does help remind students that there are specific rules regarding plagiarism and documentation, and that they should heed those rules as they research and complete assignments.

### C. Social Media Guidelines Regarding Academic Honesty

Finally, a new problem facing faculty and students at KSU has been misuse of social media, particularly GroupMe, a text-based chat platform that KSU students have adopted as their online community. For every course, a student automatically sets up a GroupMe and invites the entire class using the LMS classlist.

This GroupMe serves as a wonderful resource and support for students, particularly in online courses [23]. They go there to clarify assignments, ask about due dates, discuss issues in the class, and really engage in social learning and community building. However, it is also a place where students have the opportunity to engage in academic dishonesty. Many students didn’t realize that the consequences for cheating on GroupMe were the same as cheating in the classroom. Students at the University of Texas at Austin, Ohio State University, and Louisiana State University have learned the hard way that social media can make cheating look too easy: “In 2017, Ohio State found 83 students in violation of ‘unauthorized collaboration’ via GroupMe” [24].

To help students to make good decisions regarding use of social media, we created an interactive presentation called “Academic Honesty and Social Media [25]. Figure 3 shows



the opening screen of the “Academic Honesty and Social Media” interactive presentation designed to help students make informed decisions about social media use in courses.



Figure 3. Introductory image for the resource, “Academic Honesty and Social Media”

This presentation covers three scenarios that students may find themselves in on the GroupMe. The first describes a student posting unsolicited answers to assignments. The second details a student asking for answers on assignments. The third example features a good-hearted student posting “help” on the GroupMe that veers too close to academic dishonesty. As with “Are You Ready for an Online Course?” and the documentation resources, the “Academic Honesty and Social Media” resource also comes in a zipped file SCORM version that can be uploaded to an LMS where the quiz response can be registered in the grade book.

#### D. Early Feedback

The three resources discussed in this section were only implemented in fall 2019, and there has been no survey of either students or faculty to gauge whether or not they are helpful. However, early feedback from students in our midterm course surveys showed that the “Academic Honesty and Social Media” presentation has had mixed results. On the one hand, it has made students more aware of the penalties for academic dishonesty on social media, but on the other hand, it has stifled community building in the GroupMe because of anxiety surrounding innocent mistakes. That is an unintended and unfortunate consequence that hopefully future iterations of the resource can try to reverse.

### VI. CONCLUSIONS AND FUTURE WORK

In this work, we set out to examine the early impact of faculty innovations in the field of open educational resources. Specifically, what, if any impact, have these new efforts had on student success, particularly retention and satisfaction. With these forays into open educational resources and student success resources, it is too early to have more than individual student responses and pilot

survey results. However, initial results show that students at Kennesaw State University are benefitting from adoption of OERs in the same way that students are showing benefits nationally. Also, while we will continue to update and improve the student success resources, we do feel that they are at least a helpful start. The faculty will continue to create open educational resources, including auxiliary materials and materials to support student success generally. We will continue to research the impact as the reach of these efforts becomes broader.

#### ACKNOWLEDGMENT

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# Intelligent Tutoring Systems for Generation Z's Addiction

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**Abstract**— As generation Z's big data is flooding the Internet through social nets, neural network based data processing is turning an important cornerstone, showing significant potential for fast extraction of data patterns. Online course delivery and associated tutoring are transforming into customizable, on-demand services driven by the learner. Besides automated grading, strong potential exists for the development and deployment of next generation intelligent tutoring software agents. Self-adaptive, online tutoring agents exhibiting "intelligent-like" behavior, being capable "to learn" from the learner, will become the next educational "superstars". Over the past decade, computer-based tutoring agents were deployed in a variety of extended reality environments, from patient rehabilitation to psychological trauma healing. Most of these agents are driven by a set of conditional control statements and a large answers/questions pairs dataset. This article provides a brief introduction on Generation Z's addiction to digital information, highlights important efforts for the development of intelligent dialogue systems, and explains the main components and important design decisions for Intelligent Tutoring System.

**Keywords**- *intelligent tutoring systems; machine learning; adaptive systems; artificial intelligence.*

## I. INTRODUCTION

Driven by a large amount of data (i.e., training sets) available and the developments in neural-nets, a metamorphosis to *intelligent-like behavior* is catalyzed by the increase in the processing power of parallel systems. Generation Z (or Gen Z, commonly defined as people born between 1995 and mid-2010s) the "digital natives", are becoming more influential in dictating changes in education in the years to come. Like generation Y (i.e., Millennials [1]), Gen Z accelerates the changes in higher education by employing mobile, multimedia, and online technologies. It is the generation of online connection that collaborates and wants to learn fast, adapts and wants active participation in the learning environment. Gen Z students have already entered the university level and they adopt social learning environments that directly involves them. They are the generation of *demanders* as they request services that are available anytime, anywhere. Digital tools are an addiction to many, as they participate on a daily basis in social networking, specifically in scattered cities around the globe

where the city architecture is not facilitating social face-to-face interaction.

Research from the Center for Generational Kinetics [2] shows that 95% of the Z generation has smartphones, 55% of them use phones around 5 hours a day, and 26% of them are addicted to digital content, as they spend more than 10 hours a day online. Addiction-like level involvement with digital content shows that 31% of them feel uncomfortable if they are disconnected from the phone for more than 30 minutes. A recent study on people aged between 14 to 40 in the US [3] was targeted towards the behavior, preferences, and attitudes of young people. The study revealed fundamental differences and similarities between the Y and Z generations. About 39% of Gen Z wants to learn with a teacher, while 47% of them spend more than 4 hours a day on video platforms. Compared to Gen Y, Gen Z tends to learn through self-guidance and prefers flexibility. Regardless of the differences between generations, 66% of Gen Z have a positive view of technology in education [3].

This paper is structured as follows: Section 2 provides an overview of an Intelligent Tutoring System (ITS) and the main actors involved in such systems. Section 3 highlights the main research efforts in the area, while the structure and the main components of an ITS are presented in Section 4. In the conclusion, future trends in ITSs evolution are highlighted and explained.

## II. ARTIFICIAL INTELLIGENCE IN EDUCATION SYSTEMS

Artificial Intelligence (AI) mainly resorts to machine learning algorithms to transform data in decisions and provide meaningful user-computer interaction. At the core of the machine learning methodology is a set of statistical and prediction based algorithms or constructs that allow timely big data processing and extraction of meaningful patterns. Such patterns are used to predict (hopefully with high probability, e.g., 90%+) future events/values, hence allowing automated decisions (i.e., expert decision systems) to be taken by machines, providing the user with the impression that the computing device makes intelligent choices.

Particularly interesting is the recent application of AI in intelligent tutoring for education and, as a consequence, the proliferation of ITS. The basic principle of operation and the

main actors involved in a possible AI-based ITS are depicted in Figure 1. Data about the learner may be collected from multiple venues (i.e., social networks, instructors, online course preferences, etc.) and recommendations are made based on the processing of collected information and other inputs (e.g., exam results, learner's past and current questions, instructor's feedback about the learner, peers feedback, etc.).

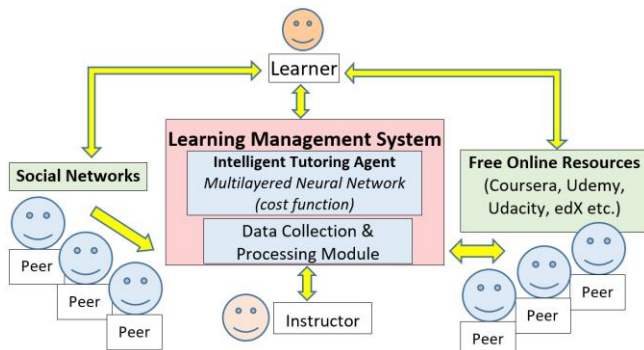


Figure 1. Possible interaction among the actors in future ITS

In the very near future, a data collection and processing module (illustrated in Figure 1) could potentially aggregate information from a variety of sources and could extract patterns specific to the learner, allowing the learner profile generation. Those patterns are further employed by the tutoring system to fine-tune the content of the conversation with the user in order to generate intelligent dialogue. A multilayered neural network, driven by a cost function, is constantly evaluating the learner's feedback and providing informed guidance to the learner.

### III. BRIEF REVIEW ON INTELLIGENT TUTORING

ITSs are not a new development, as early research efforts that focused on intelligent dialogue have been explored for several decades. Among the most notable efforts are the Hamburg Application-oriented Natural language System (HAM-ANS) project [4] at the University of Hamburg, the KLAUS project at the Scientific Research Institute (SRI) International [5] and the XCALIBUR project [6] at Carnegie-Mellon University. Central to these systems was always the requirement for interaction through sequential dialogue with a human operator and the capacity of the system to generate meaningful dialogue based on the collected data.

The rapid proliferation of automated and online learning systems has spawned in the last decade a large number of ITSs with the main goal of enabling the student to successfully solve problems. Among them, AutoTutor [7] is an intelligent guidance system that stimulates dialogue and has the pedagogical strategies of a human tutor. It was designed to help students learn the basics of hardware, operating systems, and the Internet, and enhances the learning technology in the following areas: computer literacy, critical thinking, and physics. AutoTutor focuses on meditation and pedagogical strategies and was designed

using human tutor strategies to identify motivational factors for students. AutoTutor was the basis for the development of other intelligent systems such as: AutoManager, AutoTutor-Sensitive, AutoTutor-3D [8] with interactive 3D embedded simulation, DeepTutor, AutoTutor-Lite, GnuTutor, MetaTutor - metacognition self-learning, Human Use Regulatory Affairs Advisor (HURAA) Web Counselor on ethical treatment of experimental subjects, iDRIVE - Learning to Ask Deep Questions about Science, Center for the Study of Adult Literacy (CSAL) and Operation Acquiring Research, Investigative, and Evaluative Skills (ARIES) [9].

Another prominent example is SmartTutor [10] an intelligent system that addresses two basic elements in continuous education: personalization and intelligent guidance. It contains a database of over 3000 reading and math lessons. The effectiveness of the system has been evaluated and the results have been exceptional at the K8 level. The system is based on the fact that learners' answers can provide a lot of information about the current state of their conceptual understanding. The syntactic dimension is explored in Why2-Atlas [11], an intelligent system that analyzes students' explanations of physics principles through various mechanisms. Students introduce their essays into the system as a paragraph, and the tutor uses syntactic analysis to proofread the essays and find misconceptions, as well as incomplete explanations. If the tutor identifies certain mistakes in the essay, it generates a dialogue regarding the wrong or non-existent requirements and then asks the student to correct the essay. Several iterations and dialogues can take place before the process is completed.

Along the same lines, ElectronixTutor [12] is a fully integrated system based on many intelligent learning systems (e.g., AutoTutor, Dragoon, LearnForm, ASSISTments, BEETLE-II). The system includes a student model that has knowledge of electronic circuits and guides other learners in the electronics field providing feedback. Like ElectronixTutor, e-Teacher [13] automatically builds student profiles while studying online courses and detecting the student's performance. The system suggests a customized course of action designed to support each learner.

Introductory knowledge helps learners navigate basic concepts in different disciplines. ZOSMAT [14] has been developed as an intelligent introductory system in response to the student's needs of individual learning. The role of the system is the tracking and the guidance of the learning process. It identifies and records student progress and changes the study program according to the learners' effort. It can be used for individual learning purposes, but it also provides a feature that makes it different from other intelligent guidance systems: it can be used in class under the guidance of a human tutor.

While some of these research efforts are still in the preliminary phases, there are several successful commercial applications, particularly targeted at teaching basic concepts and addressing large groups of learners, specifically at the K-12 level.

#### IV. INTELLIGENT TUTORING SYSTEMS STRUCTURE

Intelligent tutoring systems consist of four important components [15]: (1) an Expert Model (EM), (2) a Student Model (SM), (3) a Tutoring Model (TM) and (4) the User Interface Model (UIM), as illustrated in Figure 2. The data flowing among these components is constantly fine-tuned based on the system and the target users group.

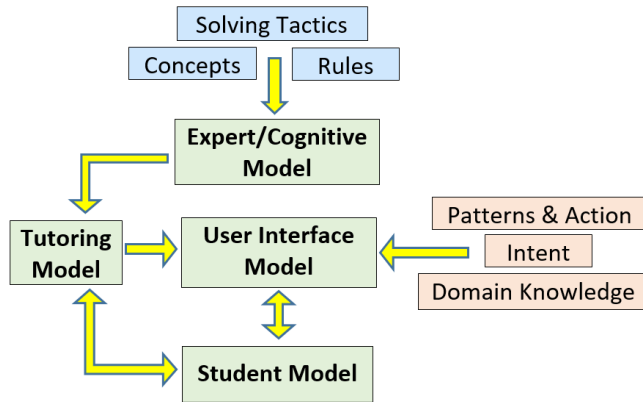


Figure 2. ITS – Generic Structure and Data Flow

The expert model (cognitive/domain model or expert knowledge model) is built on learning theories that consider all the steps required to solve a problem and contains the concepts, rules, and problem-solving tactics of the domain to be learned. The EM also contains the mal-rules and misconceptions that students occasionally exhibit. EM can fulfill several roles: a source of expert knowledge, a standard for evaluating the student's performance or for detecting errors and fallacies. Another approach for developing the EM is the constraint-based modeling approach [16], presented as a set of constraints on correct solutions [17].

The student model can be thought of as a cover on the EM. It is considered as the central component of an ITS, focusing on the student's cognitive and affective states and their evolution as the learning progresses. As the learner works step-by-step through their problem-solving process, the ITS employs a model tracing approach. If the SM deviates from the EM, the system triggers a warning and particular actions. In contrast, in constraint-based tutors, the SM is represented as an overlay on the constraint set [18] and they evaluate the student's solution against the constraint set, to identify satisfied or violated constraints. Violated constraints trigger the ITS feedback on those constraints [19], providing the learner with immediate feedback. The SM builds a profile of strengths and weaknesses for each learner relative to the EM.

Next, the tutor model (or pedagogical model or instructional model) accepts information from the EM and the SM and makes choices about tutoring strategies and actions. The TM contains several hundred production rules that exist in one of two states: learned or unlearned. Every

time a student successfully applies a rule to a problem, the system updates a probability estimate that the student has learned the rule. The system continues to drill students on exercises that require the effective application of a rule until the probability that the rule has been learned reaches the 95% threshold [20].

Last but not least, the UIM interprets the learner's contributions through various input media (speech, typing, clicking) and generates output in different media (text, diagrams, animations, agents). It integrates the following information: knowledge about patterns of interpretation (to comprehend the speaker) and action (to generate meaningful expressions) within dialogues, domain knowledge needed for content communication, and knowledge for communicative intent [21]. The communicative intent is the use of gestures, facial expressions, articulations, and/or written expressions to deliver a message and, sometimes, the ITS presents an avatar embodiment to facilitate the user interaction.

ITS are expensive systems to develop both from the complexity and development time perspectives. Attempts to develop authoring tools [22] have looked into various ways to develop agent-based tutors and dialogue-based tutors. Significant research has ensued an array of theoretical frameworks that remain enthusiastically investigated to this day. Reviews of the expert model design in [23]-[25] point to the need to extract domain based features. A review of student modeling [26] reveals the importance of specific learner's characteristics and also points out the requirement for a reward system. A detailed review of tutoring strategies is presented in [27].

Among the most important categorization dimensions for an ITS is the fundamental learning component. Three directions are possible:

- *Simulation-based* learning environments. Here, the general paradigm of a simulated world is captured in the term *reactive environment* [28] to describe an ITS in which the system responds to learners' actions in a variety of ways catalyzing learners' concepts understanding.
- *Discourse-based* learning environments. Natural language interactions have enabled more conversational forms in such environments. Discourse as a tutorial approach, is intended to operate in an ITS much like it does when practiced by a skilled human tutor.
- *Situation-based* learning. Instructional systems may be more effective when coupled with situations in which the users naturally encounter, learn, and apply the skills and knowledge being taught.

A prominent research effort, the Generalized Intelligent Framework for Tutoring (GIFT) [29] is oriented around providing three services: authoring of components, management of instructional processes, and an assessment methodology [30].



## V. CONCLUSION

The paper presents several statistical facts about Generation Z as it pertains to the use of technology for learning tasks, culminating with the need for customized intelligent tutoring systems. A brief review of the existing ITSs, as well as the fundamental structure of the ITS, is presented with a brief description of each structural component.

The relatively high cost of building an ITS makes it a viable option only for situations such as simultaneous tutoring of large groups, or in cases when tutoring redundancy is necessary and can generate significant savings (i.e., reducing the need for human instructors or freeing human instructors time and resources). With advances in processing speed and machine learning algorithms, we foresee an increase in the online deployment of ITSs and, possibly, a wider adoption of such systems among generation Z's learners.

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# Addressing Prerequisites for STEM Classes Using an Example of Linear Algebra for a Course in Machine Learning

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**Abstract**—While teaching Science, Technology, Engineering, and Mathematics (STEM) subjects, we frequently encounter situations where we have several prerequisites for a particular course. We anticipate that students will have different levels of knowledge in these prerequisites. A prerequisite (Linear algebra for Machine Learning course) was implemented as an interactive online course using Jupyter Notebooks and nbgrader. A preliminary survey shows a preference by students and instructors for this interactive implementation.

**Keywords**- prerequisites; machine learning; linear algebra; interactive self-study course; Jupyter Notebooks.

## I. INTRODUCTION

While teaching STEM subjects, we frequently encounter situations where we have several prerequisites for a particular course. We expect these students will have different levels of knowledge regarding these prerequisites. In most cases, a conceptual understanding and an ability to apply the prerequisite material are sufficient for most students. Students are not expected to know details, such as proofs, etc.

We encountered one such situation while teaching a Machine Learning (ML) course to first-year graduate students. An ML course relies on knowledge of linear algebra, multi-dimensional calculus and probability. The standard approach is to provide material for student self-study in addition to refresher material, so called crash course material given during the course. The advantage here is that students get at least the minimum amount of the required material, with an option for additional self-learning if desired.

We also encounter multiple disadvantages, however, with such an approach. For one, time needed for the main subject is spent on prerequisites. Review time for prerequisites should be limited as it is very challenging to cover necessary material at a sufficiently high level. While students have the option to self-study, learning with an instructor is significantly more effective and efficient. Another disadvantage: neither students nor instructors could verify whether the necessary level of understanding and application of prerequisite material had been achieved. This may be remedied with quizzes or tests, which in turn require additional precious instruction time.

To address these issues, we decided to use an available teaching technology: we would organize prerequisite

material in the form of interactive online self-study. We used Jupyter Notebook [1] - based technology flexible enough to create an interactive course with proper mathematical typesetting as well as programming support (Python) in case we had to do modifications which we assumed should allow us to address these issues.

Thus, instead of providing generic self-study materials for prerequisites in the form of a book or pdf, we provided a concise Interactive Online self-study course that covers prerequisites and offers Concept Inventory (IOCI) based short tests, which evaluate students' understanding of the main concepts and their ability to apply the material. Hence, we precisely target the goals of the course prerequisites.

We implemented the course using iPython Notebook [2] software with additional course management support provided by the nbgrader plugin [16]. The course was developed on Amazon's c9 cloud and was available to students online. The course works in an automated or semi-automated way, allowing the instructor to see test results by topic or intervene and comment on student answers.

In our specific case, we started with linear algebra (LA) prerequisite material for the ML graduate course. We developed prerequisite self-study course material with CI-based tests. Students can return to topics already studied, advance upon completion of an appropriate test, or skip tests altogether and concentrate on study material alone.

Our course offers a two-part novelty: making prerequisite material in the form of interactive online course; incorporating quizzes and homework in the form of Concept Inventory (CI), which addresses only required for prerequisite understanding of concepts and notions and ability to apply the material in the main course context. To the best of our knowledge, such combinations were not used before. The course was also translated into Russian and deployed at two universities: St John's University (New York) and the National University of Science and Technology, MISIS (Moscow). It covered two experimental groups with a total of 30-plus students. According to the preliminary survey, both students and instructors prefer the interactive Jupyter Notebook-based study approach to the standard prerequisite classes.

This paper proceeds as follows. In Section II, we describe existing CIs and state-of-the-art Interactive Online Systems. In Section III, we proceed to a description of LA as a prerequisite material to the Machine Learning course. We

show how CI addresses the requirement of the specific prerequisite material. In Section IV, we describe the cloud system used for the initial implementation of the course as well as hardware requirements for running a test experiment of about 200 software simulated test students. In Section V, we provide a preliminary (proof of concept) evaluation of our approach. We end our paper with a conclusion and discussion of future work.

## II. STATE OF THE ART

The purpose of a prerequisite class differs from a “normal” class. It prepares a student for another class, not directly for a future career. Hence, it is often perceived as something less necessary. As observed in [10][13], students often see prerequisites as a waste of time and avoidable. If handled appropriately, a prerequisite course would solve motivational issues. One way to minimize time and resources spent is to make it self-paced so that a student goes through it at a comfortable pace and when time is available.

The first part of the outlined program – teaching only the material actually needed - is course-specific and should be addressed on case-by-case basis.

The second part about level and form of material taught, however, can be answered in general, at least for STEM classes.

### A. Notion of Concept Inventory

While teaching STEM classes, as we observed in most cases, a conceptual understanding and an ability to apply the prerequisite material are sufficient. Students are not expected to know details, such as proofs, etc. The CI is the best existing approach to assessing conceptual understanding rather than memorization of a set of facts. CI as a form of an assessment is based on checking if a student understands basic concepts of a given subject as opposed to reciting a number of subject specific facts, equations, etc. As David Hestenes states in his paper, *Force Concept Inventory*, [17] CI Assessment is “not a test of intelligence” but rather, “it is a probe of belief systems”.

An immediate advantage of CI is that it can be used for any student. That is, it does not matter, what the subject specific background of the student is, since, as stated above, CIs do not test formal knowledge but rather understanding of basic concepts. For example, as was demonstrated in [11], there is no significant difference observed between the test results even if the class time, class readiness, or type of class are different. That includes even classes that lack traditional lectures, such as Matematica-based classes. Typically, CIs are created and delivered as multiple-choice tests. However, as opposed to standard tests CIs are not comparison tests but norm-referenced tests.

The main goal of CIs, as stated above, is to test the students understanding of basic concepts. However, a typical CI test also checks for typical misconceptions.

There are two typical types of misconceptions: general scientific misconceptions and misconceptions introduced during the teaching process – so-called didaskalogenic misconceptions. The tool CIs use for testing misconceptions is known as distractors. Basically, distractors are the answer choices, which are specifically designed to imitate typical misconceptions. Summarizing, a CI test is a multiple-choice test consisting of problems with “distractors” as incorrect options that represent typical misconceptions. Typical multiple-choice problems of this type would be:

*The following are temperatures for a week in August: 94, 93, 98, 101, 98, 96, and 93.*

*By how much could the highest temperature increase without changing the median?*

*A. Increase by 8°*

*B. Increase by 2°*

*C. It can increase by any amount*

*D. It cannot increase without changing the median.*

To answer this question, a student needs nothing more than to understand the concept of median. Yet, at the same time, the problem does check for typical misconceptions, providing possible answers that conform to concepts of midrange or mean. Indeed, option D would be true if the question would be about midrange or mean, not about median and is, therefore, a typical example of a “distractor.”

The first CI was developed and published by David Hestenes in 1992 [17]. It is known now as the Force Concept Inventory (FCI) and covers Newtonian Mechanics concepts. It had immediate success and was recognized and accepted by thousands of educators. Hestenes coined the term “modeling” to describe the conceptual approach to teaching – as opposed to the traditional factual approach. By now “modeling” approach covers well over 100,000 students each year. As a result of CI’s popularity, the American Modeling Teachers Association (AMTA) was created and grew into a nationwide community. Moreover, CIs began in various fields of engineering, science and mathematics.

CI assessment in introductory and prerequisite classes was studied, in particular in [8][9][12][20][22]. With CI the subject specific background of a given student is not significant as stated above because CIs do not test formal knowledge, but rather test the student’s understanding of related concepts, which is the student’s working knowledge.

An understanding of related concepts is exactly what is needed in prerequisite classes. Mastering prerequisite material at a working knowledge level in order to apply it to the upcoming class.

Another advantage of using CIs is that they are already developed for a wide variety of the subjects including, but not limited to:



- 1) Natural Sciences:
  - a) Physics
    - i) Force and Motion
    - ii) Electricity and Magnetism
    - iii) Statics
  - b) Chemistry
  - c) Geoscience
- 2) Engineering
  - a) Material Sciences
  - b) Fluid Mechanics
- 3) Life Sciences:
  - a) Basic Biology
  - b) Natural Selection
  - c) Genetics
- 4) Mathematics & Statistics:
  - a) Calculus
  - b) Statistics

Therefore, there already exist large depositories of test problems for many subjects in case a need to create a prerequisite class for one of such subjects.

The last aspect – the interactive, self-paced form of the class – can be addressed only through the use of technology.

#### B. Existing Interactive Online Systems

By now numerous Interactive Online Systems exist, including ALEKS [24], Cengage WebAssign [25], Knewton [26], Pearson MyMathLab Study Plan [27], Acrobatiq [28], Adapt [29], etc. All these systems offer self-paced automatically graded classes for various subjects. Typically, each such class offers an Initial Assessment and then, based on the output each student gets, activities and learning material to work on with regular re-assessments to check on progress. Such re-assessment outputs, in turn, are again used to adjust the assigned activities and learning material.

For instance, ALEKS provides the following self-description: “ALEKS uses adaptive questioning to quickly and accurately determine exactly what a student knows and doesn't know in a course. ALEKS then instructs the student on the topics she is most ready to learn. As a student works through a course, ALEKS periodically reassesses the student to ensure that topics learned are also retained. ALEKS courses are very complete in their topic coverage and ALEKS avoids multiple-choice questions. A student who shows a high level of mastery of an ALEKS course will be successful in the actual course she is taking.”

According to [18], “When asked if there are pieces of the traditional classroom setting that are lost in an online course, the overwhelming response by all recipients was the lack of professor to student and student to student interaction and communication.”

However, the classes based on such systems have several advantages over traditional classes. Such advantages include flexibility, adjustability to a student's knowledge base, pace, availability of various learning tools, timely feedback, etc. And as stated in [18], “All respondents unanimously answered that they would take an online course in the future, regardless of the challenges that they may have experienced.”

The largest summary of online vs. classroom comparison research [19] concludes that “students in online conditions performed modestly better, on average, than those learning the same material through traditional face-to-face instruction. Learning outcomes for students who engaged in online learning exceeded those of students receiving face-to-face instruction, with an average effect size of +0.20 favoring online conditions.”

At the same time, the same source states that “instruction combining online and face-to-face elements had a larger advantage relative to purely face-to-face instruction than did purely online instruction. The mean effect size in studies comparing blended with face-to-face instruction was +0.35,  $p < .001$ .” The existing systems, however, all emulate traditional classes in terms of curricula and syllabi. The only difference is the form in which the material and assessment are presented.

On the one hand, it makes the comparison quoted above reliable since there is an objective expected output for each curriculum – and the only difference is the form of presenting the material. Indeed, according to the study itself “analysts examined the characteristics of the studies in the meta-analysis to ascertain whether features of the studies' methodologies could account for obtained effects. Six methodological variables were tested as potential moderators: (a) sample size, (b) type of knowledge tested, (c) strength of study design, (d) unit of assignment to condition, (e) instructor equivalence across conditions, and (f) equivalence of curriculum and instructional approach across conditions. Only equivalence of curriculum and instruction emerged as a significant moderator variable ( $Q = 6.85$ ,  $p < .01$ ).”

On the other hand, simply emulating the existing traditional classes does not allow the online interactive form to use completely its intrinsic advantages. We do believe that prerequisite classes can benefit more from advantages that the online interactive form offers.

While a variety of platforms exist for creating online accessible interactive classes, Jupyter Notebook looks to be one of the best fits here. Jupyter Notebook makes it easy to start, further develop, and support a class. It is also quite easy to create interactive auto-graded assignments using Jupyter Notebook.

As stated in [1], “Project Jupyter is three things: a collection of standards, a community, and a set of software tools. Jupyter Notebook, one part of Jupyter, is software that creates a Jupyter Notebook. A Jupyter Notebook is a

document that supports mixing executable code, equations, visualizations, and narrative text. Specifically, Jupyter Notebooks allow the user to bring together data, code, and prose, to tell an interactive, computational story. Whether analyzing a corpus of American Literature, creating music and art, or illustrating the engineering concepts behind Digital Signal Processing, the notebooks can combine explanations traditionally found in textbooks with the interactivity of an application.”

To summarize, Jupyter Notebook allows putting together a comprehensive custom-tailored text using both newly written lectures and excerpts from existing textbooks while also supplementing the text with interactive auto-graded assignments.

Putting these three aspects together facilitates the creation of prerequisite classes that cover only the material really needed and taught in a conceptual form, assessed using the CI approach and put in a form of a self-paced interactive online class using Jupyter Notebook, or a similar platform.

### III. LINEAR ALGEBRA AS A PREREQUISITE COURSE FOR MACHINE LEARNING

The LA prerequisite class for Machine Learning class is an online interactive self-paced class built on the Jupyter Notebook platform. The lectures are based on “Linear Algebra Review and Reference” by Zico Kolter and consist of four chapters:

1. Basic Concepts and Notation
2. Matrix Multiplication
3. Operations and Properties
4. Matrix Calculus

The material presents basic definitions and concepts of LA necessary for studying Machine Learning. Each chapter is divided into smaller sections. For example, the “Matrix Multiplication” chapter is divided as follows:

- 2.1 Vector-Vector Products
- 2.2 Matrix-Vector Products
- 2.3 Matrix-Matrix Products

Each section is supplemented by an auto-graded assessment based on CI principles.

A typical problem for Basic Concepts would be:

*Find the dimensions of the matrix*

$$A = \begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \end{bmatrix}$$

- A.  $2 \times 3$  (\*)
- B.  $3 \times 2$
- C.  $1 \times 6$
- D.  $6 \times 1$

Option A is a key since the matrix has two rows and three columns.

Option B is a distractor that checks for a misconception that mixes rows with columns.

Option C is a distractor that checks for a misconception that considers a matrix as one long row with six elements.

Option D is a distractor that checks for a misconception that considers a matrix as one long column with six elements.

Another typical example:

*Matrix*

$$\begin{bmatrix} -1 & 0 \\ 0 & 2 \end{bmatrix}$$

*has eigenvalues:*

- A.  $-1$  and  $0$
- B.  $-1$  and  $2$  (\*)
- C.  $0$  and  $2$
- D. It has no eigenvalues

Option B is a key since  $(-1-x)(2-x)-0 \cdot 0=0$  has two roots:  $-1$  and  $2$ .

Option A is a distractor that checks for a misconception that defines the eigenvalues as the values of the first row elements.

Option C is a distractor that checks for a misconception that defines the eigenvalues as the values of second row elements.

Option D is a distractor that checks for a misconception that defines a characteristics polynomial as  $-1 \cdot 2 - (0-x)(0-x)$ .

In the final version assessments will be based on a sufficiently large pool of problems and will be randomly generated for each student and for each attempt.

A student is able to take this class any time before taking the Machine Learning class, at the pace that fits her or his schedule and degree of prior knowledge. In addition to the lectures, we include the option of having students ask the instructor questions or discussing any aspect of the class

with other classmates. Each assessment is auto graded but also can be graded by the instructor in case a student challenges the grade.

#### IV. SYSTEM IMPLEMENTATION

The system was initially implemented on Cloud 9 (currently Amazon c9) virtual machines with 20 Gb. hard-drive and 2 Gb RAM running Ubuntu v. 14, with Python 3.6, miniconda and installation of JupyterHub with nbgrader.

Installation was almost straightforward, the only issue being restriction on use of miniconda instead of full anaconda installation. This is due to restriction of the provided hard-drive size. The main benefit of the system was its low cost: VMs are available for free from AWS. We would like to thank Amazon for providing Cloud based virtual hardware. This essentially made our work possible.

While sufficient for development, the system nonetheless had performance issues. Thus, we had a choice either to proceed to paid Cloud based virtual machines or moved to dedicated home hosted hardware. Our choice was to move the developed system to a Lenovo P-520C workstation with Intel Xeon 6 core W-2133 Processor with vPro, 32 Gb. of RAM with dual hard-drive 512 Gb SSD and 2 Tb. HDD and 2 GB Nvidia P2000. This PC configuration proved to be sufficient to run up to 200 test students. We did not try IOCI to stress the system to run for more students.

#### V. EVALUATION OF THE APPROACH

We evaluated standard and interactive approaches by running parallel classes for over 30 graduate students taking the Machine Learning course. Half of the students studied the LA prerequisite material in the form of provided reading material. Another half used the interactive Jupyter/nbgrader online system, with a built-in auto-graded CI based tests provided for both self and regular assessment. We ran pre- and post- preparation CI-based tests that check the required comprehension of the LA material as well as a one-question survey for both instructors and students. The survey seeks to discover if the student/instructor prefers reading material or an interactive prerequisite course. An outline of the measurements approach may be found in [19]-[21][23].

Both classes offered a sample that shows prerequisite materials used by their counterparts. Both tests and survey showed a statistically significant preference of interactive prerequisite materials for students with 5% significance level.

Tests results analysis is summarized in Table 1 and uses standard  $t$  – test with a different standard deviation for testing if one of the means is larger than the other. The value of the test  $t$  shows statistical significance with a confidence level of  $\alpha = 5\%$ . Here the value  $df$  is degree of freedom,  $d$  is value of statistics,  $t$  is value of  $t$ -test corresponding values  $d$  and  $df$ .

TABLE I. ONE SIDED TWO MEANS T-TEST FOR GRADES IOCI VS READING

	IOCI	Read
N	16	15
mean	88	84
std	6	6.75

df (degree of freedom)	28.05503
d (see formula (1))	1.739542
t	0.046462

Survey preference is analyzed in Table 2 using small samples  $t$ -test for population proportion, see [14][15]. A summary of analysis is offered below in the Table 2. Here, the value of  $N-2$  is the degree of freedom, the value  $d$  is calculated as [14][15]:

$$d = (ae - bc) \left( \frac{N-2}{N(nac+mbe)} \right)^{\frac{1}{2}} \quad (1)$$

and values of the variables  $a, e, b, c, N, n, m$  used in the formula are the corresponding ones in the numerical data below.

TABLE II. SMALL SAMPLES T- TEST FOR POPULATION PROPORTIONS COMPARISON

	IOCI Users	Read Users	Total
Prefer IOCI	a = 14	b = 8	s = 22
Prefer Read	c = 2	e = 7	f = 9
Total	m = 16	n = 15	N = 31

N-2	29
d	2.186271331
t	0.018506791

A similar implementation with similar results (translation of the material into Russian) was done at the National University of Science and Technology, MISIS (Moscow).

#### VI. CONCLUSION AND FUTURE WORK

The issue of prerequisites impacts many STEM courses because many major courses require a deep understanding of Mathematics, Statistics, etc. This may be challenging in situations where graduate students wish to enroll in major courses at the start of their studies. We encountered such a situation with Machine Learning courses, which require knowledge (or at least a conceptual understanding and hands-on ability) of LA, Matrix Calculus, Probability and Statistics. Standard approaches require that students wait a

year during which they complete all prerequisites or attack prerequisites as reading material. As the latter approach has several disadvantages, we decided to make prerequisite material more attractive by implementing it using JupyterHub and nbgrader as a self-study interactive course with auto-grading. CIs are used to check how well students understand the material. Students have access to self-check exercises and feedback; instructors can monitor student's success and, if needed, recommend some adjustments. We ran it on an experimental group of students, and both students and instructors prefer this form of study over reading material.

We would like to emphasize that this approach can by no means compare in depth and outcome to regular courses on the topic. As we saw in multiple cases, this approach is used mainly because of students' schedule conflicts or a desire to expose students to major courses as soon as possible.

We plan to run the LA prerequisite course by larger numbers of instructors and students and incorporate comments and suggestions from all participants. We further intend to offer the course as open source available to anyone.

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# Exploring Blockchain for Public Sector Recruitment

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**Abstract** - Enhancing the management of human capital resources in the Greek public sector addresses the challenges of optimizing the civil personnel recruitment process, increasing public integrity while enforcing the principles of transparency, participation, accountability, effectiveness and efficiency. The objective is the design and activation of a central, unified Human Resources Management System (HRMS) both in terms of procedures, methods and IT infrastructure. Blockchain technology adopted for the needs of public administration recruitment in Greece and the expected results are described. The importance of working within an established legislative framework in which merit is well defined, job requirements reflect occupational requirements and illustrates the assessment practices from the Greek public service are set out.

**Keywords** - Blockchain, Public sector recruitment, Qualification, Verification, Evaluation

## I. INTRODUCTION

Public sector organizations are expected overtime to fulfill mandates revolving around objectives such as qualitative and cost-effective service delivery as well as accountability in the management of various types of resources. To achieve that, effective assessment in recruitment of the most qualified personnel is of the essence. Carrying out this complex procedure with the use of multiple assessment tools and information collected from diverse sources is expected to provide a more comprehensive approach of the candidates being assessed and further added value to the recruitment system overall. Securing access to the candidates' work and educational background as well as performance reviews in a credible way is argued that it will, the least, improve the current recruitment process in view of the aforementioned mandates. Blockchain technology is regarded as a game-changer in several sectors including the domain of HR and recruitment, mainly because of its inherent characteristics of decentralization, transparency and immutability. There are currently numerous business and research, private and public sector endeavors to explore both the theoretical and practical implications (technical, political, socio-economic, legal and cultural) of the blockchain technology. The purpose of this paper is to report on the development of an innovative assessment tool being designed whilst making most use of the Blockchain technology that will ultimately provide ASEP with the means to optimize the personnel recruitment process for the Greek public sector it has been entrusted with.

## II. PUBLIC SECTOR RECRUITMENT IN GREECE

### A. Legal framework

ASEP (Supreme Council for Civil Personnel Selection) is an independent body provided under the Greek constitution, entrusted with performing public administration recruitment processes for project agreements as well as fixed-term and short-term employment agreement positions at all levels. ASEP is supported by a high-end electronic information system managing the vast volume of applications, vacancies, news releases, results and most importantly candidates involved in ASEP selection processes records. Candidates are evaluated based on the score they achieve in written exams, the outcome of their interview and their qualifications overall. Some of the tools missing from ASEP's day-to-day business are functionalities that could relieve the public from the bureaucratic burden (such as achieving validation, i.e. confirmation of authenticity, of university degrees) and further enhance qualitative and cost-effective service delivery and accountability (by way of, amongst others, simplifying the already complex recruitment process of Highly Qualified Civil Personnel).

Under the current legal framework, ASEP is entrusted with performing public administration recruitment processes in Greece, apart from certain exceptions provided by law. More specifically, certain Greek public entities are empowered by the said legislation to proceed with recruitment of personnel, either supervised by ASEP or not. It should be noted that ASEP's competence to supervise the recruitment process of such a public entity does not in any case overlap with the entity's competence to deliver that recruitment process.

### B. Process

Vacancies in the civil sector are made public by ASEP through newsletters, its official website ([www.asep.gr](http://www.asep.gr)) and the press, in a non-personalized way whatsoever. Citizens can make queries via its website about announced vacancies looking for those that better match their qualifications. Following announcement, citizens sign in to the ASEP Registry where they fill in their qualifications and submit an e-application regarding the announced vacancies. The e-application itself does not suffice as the candidates are

further expected to print out their e-application and send it to ASEP along with the hardcopies of all supporting documents and certificates. ASEP's Central Committee then issues and publishes interim results in the form of tables containing all necessary information (eg. name, ID number, credits collected per qualification etc.) which may be appealed by those with vested interest. ASEP's Council Members in composition review the appeals and the interim results, issue and publish the final results.

Vacancies in the public sector addressed to highly qualified candidates, although announced and handled similarly with the rest (application process, interim and final results and so forth), is significantly more complex to the extent one more step in the recruitment process, just before the issue of the interim results, is added. More specifically, ASEP's Evaluation Committee issues (for internal use only) an initial ranking based on candidates' declared qualifications and assessment methodology that varies as it is left by law to the Committee's discretion to decide upon this each time. The candidates ranking high are then called for an interview and the Committee, upon evaluation, issues and publishes interim results in the form of tables containing all necessary information (eg. name, ID number, credits collected per qualification etc.) which may be appealed by those with vested interest. ASEP's Council Members in composition review the appeals and the interim results, issue and publish the final results.

Following the announcement of the final results in both scenarios as described herein above, the public entities who triggered the recruitment process proceed with hiring the prevailing candidates as per ASEP's results and validating their qualifications. In case of fraud detection, public entities may submit, within three years from the final results publication, a request to ASEP for replacement.

### C. Drawbacks in the current process

Qualifications' evaluation by ASEP (initially by the Central Committee or the Evaluation Committee as per the case and later by the Members in composition) is a time-consuming process as it is performed in a non-automated way. Qualifications' validation by the public entities who trigger the recruitment process and ultimately hire the prevailing candidates as per ASEP's results is also performed in a non-automated way. Both processes are apparently time-consuming, notably the validation of qualifications requires exchange of letters and, in certain cases, circulation of hardcopies, with all the cost that the stakeholders at issue incur with regard to time, money and manhours. The replacement process itself is time-consuming and linked with both direct and indirect costs.

## III. QUALICHAIN POTENTIAL

QualiChain targets the creation, piloting and evaluation of a decentralised platform for storing, sharing and verifying education and employment qualifications and focuses on the assessment of the potential of blockchain technology, algorithmic techniques and computational intelligence for

disrupting the domain of public education, as well as its interfaces with private education, the labour market, public sector administrative procedures and the wider socio-economic developments.

## IV. PUBLIC ADMINISTRATION RECRUITMENT PILOT

QualiChain pilot goals in relation to public sector recruitment are the following:

- Demonstrate and assess the QualiChain concept and technological solution, by piloting the combination of disruptive technologies involved in the context of staffing the public sector.
- Assess the impact, i.e. the benefits and risks of the QualiChain technological solution on the full spectrum of stakeholders towards which it is addressed in public administration.

### A. Stakeholders

The stakeholders involved in the ASEP use case are the following:

#### 1) ASEP Council Members and Employees:

As publishers, evaluators, validators, and decision makers with regard to the candidates' qualifications and the entire selection process in general.

#### 2) Citizen/Candidate:

As the main participant of a selection process and the owner of qualifications.

#### 3) Public Entity:

As "customer" of ASEP selection process and the future employer of the candidate.

#### 4) Qualifications' issuing/accrediting institutions and their personnel:

As (indirect) providers of qualifications or on the receiving end of requests for verification, by public entities.

### B. Expectations

The recruitment and competency management services of QualiChain will be exploited to enhance not just the check of the candidates' declared qualifications, but also their screening leading to a short list of those to be interviewed and ultimately to the identification of the best possible applicant for the role.

Specifically, this pilot has the following main expectations as illustrated in "Fig. 1":

- To provide personalised candidate notifications for job vacancies by matching individual profiles with available jobs in the civil sector.
- To utilise the solution's Blockchain based digital ledger in order to validate academic and professional qualifications of individual candidates.
- To improve efficiency of the selection process in terms of time and credibility.

### C. Use case steps

The Highly Qualified Civil Personnel recruitment process steps are the following:

1) The issuing organization issues a qualification component (either an academic qualification or a work experience certificate) for a citizen.

2) The issuing Organization, after obtaining the candidate's consent, uploads the qualification component in QualiChain and sends it to the Citizen.

3) ASEP announces positions/vacancies on QualiChain.

4) Citizen/Candidate gets notified of new vacancies via a Data Analytics Tool embedded in QualiChain.

5) Candidate signs up to ASEP's Registry (if not already registered), fills in his qualifications, uploads the relevant proof of qualifications declared (e.g. university degree) and applies for the vacancy they are interested in.

6) ASEP confirms the validity of the proof of qualification declared and potentially its metadata (e.g. year of graduation).

7) ASEP marks the qualification, the validity of which has been confirmed to its Registry, as a Level 6 qualification. A Level 6 registered qualification means that this process does not have to be repeated for this qualification.

8) ASEP uses QualiChain 's MCDSS (Multi Criteria Decision Support System) to get an initial ranking of candidates.

9) Based on this initial ranking, ASEP proceeds to the stage of interviews.

10) ASEP uses QualiChain MCDSS to get the final ranking and ultimately the interim results.

#### D. Challenges

Several challenges have been identified from the beginning as follows:

- Friendliness and usability of user interface provided by Qualichain, given that it will be, mainly, used by ASEP'S Members and employees, of no technical background whatsoever.

- Pilot planning and integration with internal ASEP procedures.
- Semantic interoperability between Greek terms used by ASEP information systems (e.g. institution names, qualifications, certifications, job descriptions and so forth) and QualiChain terminology.
- Compliance with Greek and EU regulation e.g. General Data Protection Regulation (GDPR).

#### V. CONCLUSION

In order to achieve effective assessment in recruitment of the most qualified personnel in the public sector, methods and tools must be constantly developed and tested to educate and train everyone in line with new developments, in our case, with the blockchain technology, so that their benefits can be fully realized by all stakeholders. The opportunity to explore an area that has not had much attention academically, i.e. public sector recruitment process from a different angle, that of embedding highly sophisticated tools, enables this effort to be treated as a breakthrough in contemporary recruitment processes, not necessarily restrained in the civil sector.

#### ACKNOWLEDGMENT

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## Greek Supreme Council Of Personnel Selection



Candidate



Candidate Notification



Qualification Validation



Efficiency



Improve Selection Process



Educational  
Institute

## QualiChain

Figure 1. Pilot objectives



# Blockchain Applications in Education: A Case Study in Lifelong Learning

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**Abstract**—This paper presents a pilot case study of the QualiChain project, aiming at supporting lifelong learning through the combined use of Smart Badges and personalised recommendations. The pilot case study uses Blockchain technology as a means to decentralise lifelong learning and provide lifelong learners with transparent and immutable educational accreditation. At the same time, lifelong learners are provided with personalised recommendations that help them reach their personal and professional learning goals.

**Keywords**—lifelong learning; blockchain; decentralisation; smart badge; personalised recommendation.

## I. INTRODUCTION

Education today is still controlled mostly by educational institutions, which offer quality, credibility, governance, and administrative functions. This model is not flexible enough and poses difficulties in recognising the achievements of a lifelong learner in informal and non-formal types of education. As a result, a lifelong learner's transition from formal to informal education and vice versa can be hindered, as the achievements acquired in one type of education are not easily transferable to another [1][2]. Generally, lifelong learners have limited control and ownership over their learning process and the data associated with their learning.

This indicates the need for a decentralised model across all types of education, offering learners with a framework for fully controlling how they are learning, how they acquire qualifications and how they share their qualifications and other learning data with third parties, such as educational institutions or employers [3][4]. In this paper, we investigate how Blockchain technologies can help realise this vision via a pilot case study for offering support to lifelong learners in various stages of their learning journeys and of their career trajectories.

The remainder of this paper is organised as follows. In Section 2, we introduce the overall framework of the QualiChain project. We then proceed in Section 3 to present the pilot case study for supporting lifelong learning, its scope, the stakeholders involved, the main scenario, as well as the outcomes of a series of consultation workshops about this pilot. Finally, in Section 4 we conclude the paper and outline the next steps of this work.

## II. THE QUALICHAIN PROJECT

The emergence of the Blockchain promises to revolutionise not only the financial world, but also education in various ways. Blockchain technology offers a decentralised peer-to-peer infrastructure, where privacy, secure archiving, consensual ownership, transparency, accountability, identity management and trust are built-in, both at the software and infrastructure levels. This technology offers opportunities to thoroughly rethink how we find educational content and tutoring services online, how we register and pay for them, as well as how we get accredited for what we have learned and how this accreditation affects our career trajectory.

The QualiChain research and innovation project focuses on the assessment of the technical, political, socio-economic, legal and cultural impact of decentralisation solutions on education. As shown in Figure 1, QualiChain is targeting four key areas for exploring the impact of decentralisation: (i) lifelong learning; (ii) smart curriculum design; (iii) staffing the public sector; (iv) providing HR consultancy and competency management services.

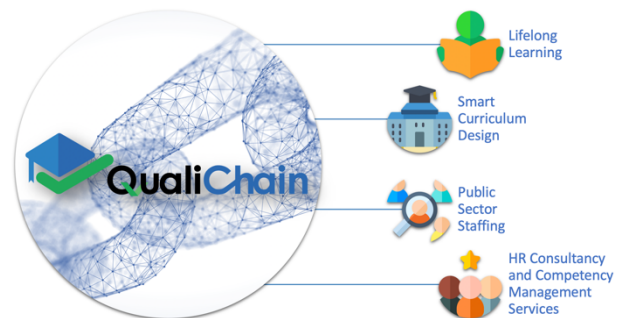


Figure 1. The key areas targeted by the QualiChain project.

QualiChain investigates the creation, piloting and evaluation of decentralisation solutions for storing, sharing and verifying education and employment qualifications and focuses on the assessment of the potential of Blockchain technology, algorithmic techniques and computational intelligence for disrupting the domain of public education, as well as its interfaces with private education, the labour market, public sector administrative procedures and the wider socio-economic developments.

### III. SUPPORTING LIFELONG LEARNING

As outlined in the previous section, lifelong learning is a key area targeted by the QualiChain project. We are therefore aiming to provide support to lifelong learners in various stages of their learning journeys and of their career trajectories. In the context of this pilot case study, we investigate how Blockchain technologies can support lifelong learners in their learning journey and in advancing their career. Figure 2 illustrates the main goals of this pilot, which are the following:

- Awarding lifelong learners with **transparent and immutable educational accreditation**.
- Offering lifelong learners **personalised recommendations** based on their learning achievements.
- Supporting lifelong learners in reaching **their personal and professional learning goals**.

The next sections describe the scope, stakeholders and main scenario of this pilot, as well as the outcomes of a series of consultation workshops about this pilot.



Figure 2. The overall goals of the pilot on supporting lifelong learning.

#### A. Scope

The scope of this pilot case study spans across the following:

- We are targeting both **formal and informal learning**. While formal learning typically happens inside the classroom, for example in a traditional university lecture, informal learning happens outside of the classroom, for example by studying free online courses.
- We are targeting both **academic degrees and other forms of educational accreditation**. For example, open badges have emerged as a new form of certifying that someone has acquired certain skills and has gained specific knowledge upon fulfilling certain criteria, e.g. by completing an online course.
- We are supporting the **learning journey and career trajectory of learners**. We are aiming to support the whole learning journey of learners by offering them recommendations on what to study next. We are also

offering recommendations about their next career steps, based on the educational credentials they have acquired.

#### B. Stakeholders

The two main categories of stakeholders involved in this pilot are the following:

**Lifelong learners.** The concept of “lifelong learning” is based on the fact that learning is not confined to childhood or the classroom, but can take place throughout life and in a range of situations. Lifelong learners pursue learning throughout their lifetime, for either personal or professional reasons. They may study to develop new skills that they need in their professional life, for example to advance their career by finding a new job or by being promoted in their current job. They may also study to acquire skills and knowledge for personal reasons, for example as a hobby of theirs. Lifelong learners may engage either formal or informal education, or both, depending on their current learning goals and personal or professional circumstances.

Lifelong learners face various challenges associated with the recognition of their learning achievements, for example when transitioning from formal to informal education or vice versa. In this pilot, we seek to support them in various ways, for example by verifying their learning achievements on the Blockchain, or by offering them personalised recommendations about what to study next or which job position might be suitable for them. In this way, we aim to help lifelong learners reach their personal or professional learning goals.

**Educational institutions.** These are institutions that provide education or training services, either paid ones or free. The offerings of educational institutions can vary from conventional offline degrees to online free or paid courses, such as Massive Open Online Courses (MOOCs) or Open Educational Resources (OERs) [5].

In the context of this pilot, we seek to make the awarding of accreditation by educational institutions transparent and immutable with the use of Smart Badges [6]. Smart Badges are dynamic records of accreditation that follow the same principles as Open Badges [7] and offer the same benefits in recording accreditation. However, Smart Badges are immutable and easily verifiable as they are stored on the Blockchain. The other novelty of Smart Badges lies in their dynamic features. For example, apart from just recording a learning achievement, a Smart Badge can also offer job or course recommendations as described in the next section.

#### C. Scenario

In this section, we present the interactions between stakeholders in the context of the main scenario of this pilot, as illustrated in Figure 3. Let us consider a lifelong learner, Michelle, who is looking to expand her knowledge and skills on data science, and has thus enrolled to a number of courses offered online, including MOOCs and OERs. Each time she completes a course, she is awarded a Smart Badge by the educational institution that offers the course. This Smart Badge includes data about the skills that Michelle has acquired upon completion of the course. Each Smart Badge

Michelle earns is verified and stored on the Blockchain as part of her personal ePortfolio.

After studying for several months, Michelle has mastered some basic data science skills, including various computer science topics such as databases. Based on these skills, the Smart Badges generate recommendations about jobs that may be suitable for Michelle. Michelle receives personalised recommendations about jobs that fully match her skills, as well as about jobs that match her skills partially. Michelle may also further personalise these recommendations and filter them according to her specific criteria, such as the location of the job, salary, employer, etc.

Michelle is interested in one of the jobs that matches her skills partially. She then receives recommendations about courses that will give her the additional skills required for this job. Michelle enrolls for these courses, in order to acquire the needed skills. When she has acquired them, she proceeds to apply for her desired job and allows the prospect employer to access the relevant Smart Badges from her ePortfolio. By using this Blockchain-based infrastructure to support her in her studies, Michelle has adopted a more efficient and targeted approach to learning, towards achieving her desired career trajectory.

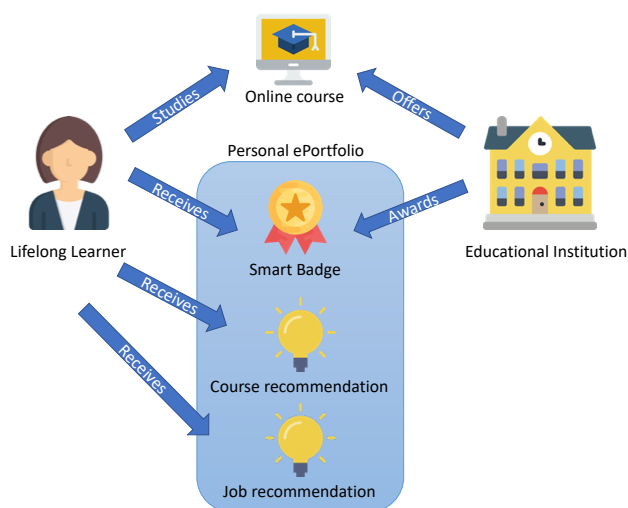


Figure 3. Stakeholder interactions in the main scenario of the lifelong learning pilot.

Our early work on implementing this scenario can be found at [6]. This implementation has been based on the use of Smart Contracts for the Ethereum Blockchain platform [8]. Smart Contracts are defined as “automatable and enforceable agreements” [9] and they constitute one of the main features of current Blockchain platforms, including Ethereum. In order to collect job market data, we are harvesting datasets of current job offers and their associated skills from a job aggregator that has been developed by the European Data Science Academy (EDSA) project [10]. These datasets are placed in Smart Contracts on the Ethereum Blockchain and are then used for matching jobs with a learner’s badge-based skills. In this way, the awarded badges are smart, in the sense that they are being used to offer recommendations to learners.

#### D. Consultation workshops

In order to further develop our pilot case study and to better understand the current needs of our stakeholders, we have performed a series of consultation workshops (Figure 4). These workshops have targeted different audiences in the context of renowned international conferences on open education and educational technology. So far, the workshop series has been delivered in the context of the following events:

- The EATEL Summer School on Technology Enhanced Learning (JTELSS 2019), 3-7 June 2019, Bari, Italy.
- The Association for Learning Technology Conference (ALTC 2019), 3-5 September 2019, Edinburgh, UK.
- The Online, Open and Flexible Higher Education Conference (OOFHEC2019), 16-18 October 2019, Madrid, Spain.
- The Open Education Global Conference (OE Global 2019), 26-28 November 2019, Milan, Italy.



Figure 4. Snapshots from the consultation workshop series.

Participants in these workshops have been early and late career researchers, lecturers, technologists and professionals from the educational sector. During the workshops, participants were introduced to the overall framework of the QualiChain project, as well as the scenarios that apply Blockchain technologies in education. In particular, participants explored the ways that ePortfolios, accreditation, tutoring, as well as other aspects of teaching and learning can evolve within a decentralised ecosystem based on the Blockchain.

#### E. Findings

In order to document requirements for the further development of our pilot case study, we asked participants of



our consultation workshops to produce learning scenarios that make use of Blockchain technologies in the context of lifelong learning. More specifically, participants were asked to work in small groups in order to brainstorm the following aspects of learning scenarios:

- *Persona(s)*: Who are the typical users in this scenario and what do they wish to accomplish?
- *Requirements*: Documented in the following format: As Persona "X", I want to do "Y", so that I achieve "Z".
- *Use of Blockchain*: How can the Blockchain be used in this scenario?
- *Related resources*: Any links/publications/other resources that are relevant to this scenario.

These group brainstorming activities were followed by plenary discussion sessions, where participants presented and discussed their scenarios. Figure 5 summarises the main findings from the group activities and discussion sessions. These findings are presented in the form of requirements derived from the learning scenarios produced by participants of the workshops, as well as from the main takeaway points of the discussion sessions.



Figure 5. Requirements collected from the participants of the consultation workshop series.

First of all, participants pointed out the need for ePortfolios to aggregate both formal and informal qualifications that will be easily validated by employers and educational institutions. This will help streamline the admission processes in universities and the hiring processes by employers, as well as eliminate falsified qualifications.

Participants also highlighted the need for learners to be guided on how to build lifelong learning pathways in order to achieve their learning goals. These learning goals can be

aligned with job market needs for improving the learner's employability, or they can be associated with the learner's personal progression ambitions. Acquiring micro-credentials can help lifelong learners achieve these goals by studying short online courses and earning professional or academic credentials [11][12]. Micro-credentials are rapidly emerging and gaining popularity among lifelong learners, as they address their needs for granular certified learning. Renowned educational institutions from around the world are currently offering a continuously increasing range of micro-accredited courses, thus providing opportunities to pursue further study in a variety of specialised fields [13]-[16].

Career counselling was also featured in the learning scenarios and discussions of participants of the workshops. It was pointed out that job seekers are in need of acquiring a comprehensive overview of the job market and the latest market trends, so that they can make informed decisions about the next steps in their careers.

Finally, data ownership and privacy requirements were deemed quite important by participants of the workshops. It was highlighted that learners and job seekers should own their digital identity and the data in their ePortfolio. Additionally, they should be able to control who accesses their identity and their ePortfolio, which data are accessed and for how long.

These requirements largely validate the scope of the QualiChain lifelong learning pilot, while helping us further expand it. In particular, we will be addressing the validation of both formal and informal qualifications in the form of Smart Badges. We will also be facilitating the building of lifelong learning pathways via personalised course recommendations, which will help learners choose their next online or offline course, towards achieving their learning goals. Additionally, the personalised course recommendations will include micro-accredited courses, in order to facilitate the acquisition of micro-credentials by lifelong learners.

With regards to the career counselling requirement, personalised job recommendations will provide job seekers with advice on their next career steps. We are also contemplating offering detailed overviews of the job market and its latest trends via interactive dashboards, based on the ones we have developed in the context of the EDSA project [10].

We will be extending our pilot case study to address data ownership and privacy requirements by employing decentralisation solutions, such as the Solid platform [17] and the FAIR TRADE framework [18]. Solid is a decentralised platform for social web applications, where the data of users is managed independently of the applications that create and consume this data. This approach enables users to choose where their data resides and who is allowed to access it. The FAIR TRADE framework builds on top of the Solid approach by defining a set of dimensions relevant to data management in decentralised contexts. The framework can therefore be used for describing and evaluating the management of decentralised data solutions, as well as for the development of best practices in the developing field of decentralised data management.

Finally, we will be looking into ways of implementing Self-Sovereign Identity (SSI) for learners and jobs seekers. SSI is a technology that adds a layer of trust to digital interactions, thus allowing individuals to own and manage their digital identity [19]. There are several implementations of SSI in the literature, largely based on the use of Blockchain technology [20]-[22].

#### IV. CONCLUSIONS AND NEXT STEPS

This paper has presented a pilot case study for supporting lifelong learning via Smart Badges and personalised recommendations. The pilot case study employs Blockchain technology for providing lifelong learners with transparent and immutable educational accreditation. It also uses personalised recommendations for helping lifelong learners reach their personal and professional learning goals. This pilot is part of the QualiChain initiative for decentralising education and employment qualifications using Blockchain technologies.

Engaging the communities of stakeholders has provided us with a valuable insight into the lifelong learning challenges they face and their proposed solutions. This insight will help us further shape the requirements and the implementation of our pilot. We will continue consulting with the communities of stakeholders throughout the different implementation phases of our pilot, so as to better understand and address their needs.

#### ACKNOWLEDGMENT

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# Using Blockchain, Semantics and Data Analytics to Optimise Qualification Certification, Recruitment and Competency Management: a Landscape Review

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**Abstract**—In the era of digitisation, innovative technologies and Information & Communication Technology (ICT) systems have transformed many areas and domains. The same cannot be said for Higher Education, especially as this concerns the certification of degrees, qualifications and other accreditations of students and job seekers that are still largely in paper form and require manual and time-consuming processes. Given that such documents are pertinent not only for education purposes but also for the job market and Human Resources-related (HR) processes of private and public organisations, there is a growing need for automatic and trustworthy systems that can handle qualification certification while at the same time providing added value for the job market. This paper is written under the context of the European Union (EU)-funded project QualiChain that aspires to investigate the impact of disruptive technologies, such as blockchain, semantics, data analytics and gamification in the domain of public education, as well as the interfaces of the latter with the fields of private education, the labour market, and public sector administrative procedures.. The scope of this publication is to perform a landscape analysis on commercial tools and frameworks that operate in the aforementioned domains and compare them to the projected functionality of the QualiChain platform.

**Keywords**—*blockchain; semantics; data analytics; state-of-the-art; qualification certification; human resources management.*

## I. INTRODUCTION

When referring to qualification certification, the most common thought is a higher education diploma, a piece of paper that states the knowledge that has been acquired in a certain scientific field, or the skill to develop a task. The

certification body is the entity that provides a certification for this diploma and is the legal recogniser of the knowledge. A typical, paper-based education certificate is a document that states that a person has received specific education and/or evidence of achievement of expected learning outcomes. Education certificates are used for a variety of purposes, such as the recognition of the completion of a specific learning experience by a student; or the achievement of a defined amount of knowledge achieved in a specified area; the acquisition of skills or the attainment of a particular excellence criterion.

Despite the fact that education certificates find use in various educational and work related processes (individuals' further admission in other educational and training programmes, personnel recruitment, etc.), they are largely resisting the pull of technology, as they are still held in diverse formats in siloed databases, often involving paper documentation and extremely time-consuming manual processes for their verification [1]. Additionally, most higher education institutions operate in isolated environments with no connection to the respective labour market that their graduates are projected to follow. As such, in most cases there are no tools that can ease the transition of a person from being a student to a job seeker and the connection between academia and the labour market is in most cases non-existent. Consequently, there is a clear lack of a trustworthy and automatic solutions when it comes to archiving, managing and verifying educational qualifications that can operate in various settings and provide added value to its users.

The slow digitisation of the education sector [2] coupled with the lack of suitable ICT solutions for education

credentials' verification, means that holders of such titles are dependent from issuing/accrediting authorities every time they want to verify their degrees. This fact does not only affect academic institutions but also private and public organisations in their HR-related tasks. For example, recruitment in an organisation requires combing through hundreds of candidates' résumés, weeding out the unqualified ones and narrowing down the rest into a group of potential recruits', whose qualifications and academic degrees have to be checked and validated on a case-by-case basis. However, difficulties in the public and private sector do not limit to the actual task of recruiting but extend to a wider set of processes that follow contracting activities, indicatively encompassing personnel allocation and re-allocation, staff mobility, and skills' development and evaluation.

Solutions to these difficulties require fundamental changes in work practices and processes that extend beyond the transformation of the recruitment procedure itself and trace back to the way education and employment credentials and qualifications themselves are archived, managed and used and thereby to the way the educational and other accrediting organisations operate. Disruptive technologies, such as blockchain, algorithmic techniques, data analytics and semantics and innovative concepts like gamification may offer solutions to these challenges. Particularly, blockchain, as a decentralised, permanent, unalterable store of information can help with the archiving and trust issues, as well as provide a frictionless method for transacting with others, whereas computational intelligence found in the technological domains of algorithmic techniques, data analytics and semantic analysis may facilitate decision making and optimise work practices and procedures.

To assess the added value that this combination of technologies might provide to the aforementioned challenges, it is imperative to assess and evaluate similar frameworks and tools that operate in the domains of education and the labour market and provide solutions for qualification certification, recruitment and competency management. Under these circumstances, this paper presents a state-of-play analysis on 19 tools and frameworks that were identified in these domains. This analysis was performed under the context of the EU funded project QualiChain that aims to combine blockchain, semantics and other innovative technologies to provide a holistic, trustworthy and automatic solution in the challenges presented above.

Section I introduces the scope of this paper by presenting the current situation and challenges arising from the lack of technical solutions for qualification certification. Section II introduces the QualiChain project and the platform's functionalities. Section III outlines the criteria used for the analysis and provides a short description of each tool and framework that was analysed. Finally, Section IV presents the conclusions of the analysis.

## II. THE QUALICHAIN CONCEPT

QualiChain is a project that aspires to investigate the impact of disruptive technologies, such as blockchain, semantics, data analytics and gamification in the domain of

public education, as well as the interfaces of the latter with the fields of private education, the labour market, and public sector administrative procedures. The project concept lies in applying the aforementioned technologies for the design, implementation, piloting and thorough evaluation of the QualiChain technological solution, a distributed platform targeting the storage, service, and verification of academic and employment qualifications [3]. Apart from educational and professional certificates verification, QualiChain aims to develop various added-value tools that can provide solutions to major challenges in the domains of education and the labour market. In fact, QualiChain services are structured along two main pillars, i.e., baseline and value adding services. The first pillar is grounded upon QualiChain main technological foundations, namely blockchain and semantics, enabling educational awards' and other qualifications' archiving and storing, awards' verification, the latter incorporating, if needed, certificates' translation and equivalence verification, as well as qualifications' portfolio management. The second pillar will build upon QualiChain baseline services to offer with the help of the computational intelligence, embodied in data analytics and decision support algorithms, as well as gamification techniques, a set of more advanced services, including career counselling, intelligent profiling, and competency management and within the context of the latter recruitment and evaluation support, and consulting.

## III. RELATED TOOLS AND FRAMEWORKS

### A. Comparison Criteria

The comparative analysis in the following sections pertains to the current state of practices regarding tools, methods and frameworks, similar to QualiChain that are used in education and public administration, as well as commercial applications, and that all the tools presented therein are released for use and are not under development. In addition, the tools and frameworks described are not expected to include every projected function of QualiChain given that their scope is much more specific. What is useful though, is to perform a comparison on the state-of-play of functionalities and technical capabilities included in such systems to identify innovative ideas or potential shortcomings of existing solutions. Consequently, for this comparison the criteria for the analysis largely represent the high-level technical capabilities of the various modules of the QualiChain platform and are the following:

1. Target users: This part of the analysis will help assess if the list of stakeholders identified for the projected QualiChain platform is as complete as possible.
2. Blockchain usage/Data security: Identify the solutions that employ blockchain or other data security methods
3. Personalisation approach: This criterion will help compare the various approaches that make the tools more user-centric
4. Use of Semantics/data interoperability: Distil the tools that provide the capability for data analytics and in less innovative solutions other searchable interfaces as well as the available pool of data.



5. Gamification approach: Identify approaches that increase user engagement
6. Qualification certification and Multilinguality: This criterion pertains to the tools that certify qualifications. Two important sub-criteria here further divide the tools into automatic and non-automatic as well as the capability to translate degrees in multiple languages
7. Recruitment & Competency Management: This criterion pertains to the solutions that offer to organisations the ability to perform various HR related tasks.
8. Open source/APIs: This criterion will help identify the openness of each tool and the potential to create synergies with QualiChain.

#### B. Selected Tools & Indicative Analysis Tables

The tools and frameworks analysed under the context of this publication were the following:

1. Qualification Check [4] (tool): Qualification Check offer a global solution for qualification verifications, supported by a team of multilingual education experts. Qualification Check provides qualification validation to help stop the damaging and costly effect credentials fraud has on organisations.
2. Recognition Finder [5] (tool and framework): Recognition Finder is a tool for the recognition of foreign professional qualifications in Germany. It presents important information about the legal foundations, the recognition procedures for individual occupations and the available counselling services in a concise form. The tool is not automatic but rather finds the competent authority that the user needs to contact for the respective occupation.
3. European Credit Transfer & Accumulation System [6] (credit and grading system): ECTS is a credit system designed to make it easier for students to move between different countries. Since credits are based on the learning achievements and workload of a course, a student can transfer their European Credit Transfer System (ECTS) credits from one university to another, so they are added up to contribute to an individual's degree programme or training.
4. UHR Recognition of foreign qualifications [7] (tool and framework): The Swedish Council for Higher Education evaluates foreign qualifications to provide support for people looking for work in Sweden, people who wish to continue studying, or for employers who wish to employ someone with foreign qualifications. The tool includes an online application to apply for an evaluation and recognition of qualifications; however, the validation is not performed automatically.
5. ServiceNow [8] (tool): The ServiceNow module offers an expansive portfolio of training offerings across IT, HR, Customer Service and other departments that cover the Now Platform (HR and workflow organisation platform for enterprises). Moreover, it provides certifications upon mastering new features offered in the latest release of the platform, micro-certification on

a variety of subjects as well as verification of certifications received through the ServiceNow platform.

6. Teacher Certification [9] (framework): The Teacher Certification framework of the British Columbia is a framework that provides a number of services to UK Ministry-certified educators. Among them are certification services, criminal record checks and fee information. The framework includes complete instructions regarding certification offices, pertinent e-mail addresses and the complete methodological steps that a teacher should follow to complete a certain task.
7. DegreeVerify [10] (tool): DegreeVerify provides immediate online verifications of college degrees and attendance. It provides prompt access to many degree and attendance records and eliminates the complications and delays associated with manual processing through individual schools. It can also reduce the risk and cost of making bad hiring decisions as well as ensure only verified eligible student customers are eligible for receiving offers from prospective employers.
8. WES Degree Equivalency Tool [11] (tool): The WES Degree Equivalency Tool compares a user's education credentials to Canadian standards. It allows a user to select the country he/she studied in, enter his/her credentials and the tool shows the degree equivalency. The Degree Equivalency tool doesn't replace an official evaluation, but rather estimates the degree equivalency.
9. Higher Education Degree Datacheck [12] (tool): HEDD is UK's official degree verification hub, used by organisations, institutions and universities to verify degrees. HEDD cannot be used by students or graduates to verify their own rewards, which means that the organisation using the tool's services will have to request a proof of consent from the individual.
10. NOKUT Recognition of foreign education in Norway [13] (framework): NOKUT is a framework that helps institutions, organisations and universities to validate foreign higher education degrees, vocational education and training certifications. It includes an exhaustive list of regulated professions and industries and a pertinent list of recognition authorities that users of the system will have to contact to get recognised in Norway.
11. Vitnemalsportalen Diploma registry [14] (tool): The Diploma registry is a Norwegian service that helps users automatically collect results from higher education institutions in Norway and share them with potential employers, educational institutions and other relevant recipients. Moreover, all transmissions are encrypted and only the sender can decide who he/she wants to share the data with.
12. e-CF 2.0 Profiling tool [15] (tool): The objective of the tool is to bring to life the content of e-CF version 3.0 and provide linkage to the EU ICT Professional profiles. It helps users build their profiles based on their

preferred orientation (e.g., job profile or education profile) and provides comparisons between user created profiles and established ICT professional profiles to support skill gap identification. The tool also supports multiple languages.

13. CEPIS e-Competence Benchmark [16] (tool): CEPIS is a free online tool that helps assess ICT professionals' skills, based on the e-CF. This tool provides ICT professionals with a personal competence gap analysis that compares their competences against those required for a range of European ICT professional profiles. This enables individuals to plan their career development and make informed decisions about further education.
14. e-Competences assessment and certification assessment [17] (tool): This tool lets users compose their own professional profile, find the best matching ICT profiles and choose the certificates that could help them meet their aspirations. It provides users with three distinct functionalities: a self-assessment tool, comparison of e-competence related certificates and an e-competence demand and supply calculator.
15. IT Staffing Nederland [18] (tool): IT Staffing is embedding the European Competence Framework in their recruiting and matching systems, for the sake of better transparency and quality on this process. The tool takes advantage of semantics for translation of ICT texts into digital e-competences and provides transparency to better interpret job descriptions, vacancy texts, incoming CVs and training materials.
16. Blockcerts [19] (tool): Blockcerts is an open standard for creating, issuing, viewing, and verifying blockchain-based certificates. These digital records are registered on a blockchain, cryptographically signed, tamper-proof, and shareable. The goal is to give to individuals the capacity to possess and share their own official records.
17. Diplome [20] (tool): Diplome is a blockchain-powered credential evaluation service that generates a "certificate wallet", in which it is possible to upload one's qualifications, making it easier for a student, graduate or professional to enrol in a foreign university or enter the labour market in a foreign country. Diplome is a global ecosystem, which can be used by authorities and institutions to securely and unchangeably register education/training documents, guaranteeing their transferability and authenticity.
18. LinkChain [21] (tool): LinkChain is a Blockchain-enabled Linked Data Platform catered to data publishers and consumers that provides certificate equivalence verification, credential auditing & verification while supporting multi-lingual capabilities as well.

19. Blockchain for Education [22] (tool): The available blockchain tool (part of a platform that is in development) enables learners to present their digital certificates while also supporting certification authorities in the management and archiving of digital certificates. The tool relies on blockchain to enable tamper-proof archiving of certificates and their correct and permanent allocation to the learners. The existing in-use tool relies on Open Badges and uses JSON/JSON-LD for metadata and as a basis for querying (verification purposes).

For the analysis of the tools and frameworks that are presented above, the following tables (see TABLE I) were used to describe the general functionality of each tool, the technologies implemented in it and the added value that they provide to users.

TABLE I. ANALYSIS TABLE

Tool/method name		Recognition Finder[5]	
Category (tool, product, framework)	Tool and framework	Current version	Released
Description			
Recognition Finder is a tool for the recognition of foreign professional qualifications in Germany. Moreover, those seeking advice only need a few clicks and this online tool will name the competent authority for their application. In addition, it presents important information about the legal foundations, the recognition procedures for individual occupations and available counselling services in a concise form. Recognition Finder does not automatically verify the user's qualifications but finds the competent authority that the user needs to contact for the respective occupation.			
Implemented technologies and functionalities			
<ul style="list-style-type: none"> <li>Recognition check allows users to see whether their professional qualifications are recognised in Germany</li> <li>The portal is available in German and English, as well as Arabic, French, Greek, Italian, Polish, Romanian, Russian, Spanish and Turkish.</li> <li>For mobile use, there is also the "Recognition in Germany" app, which offers the information in seven languages</li> <li>The database currently contains more than 1,500 different contact addresses for the recognition procedures of occupations</li> </ul>			
Added Value			
<ul style="list-style-type: none"> <li>In the "Recognition Finder", the user can enter his or her profession and use the occupational profile displayed to determine the German vocational certificate that matches the qualifications acquired abroad.</li> <li>Just a few clicks are sufficient to get the address where an application for an assessment of equivalence can be submitted.</li> <li>All the information that is important for submitting an application is summarised – for example the documents required for an application.</li> </ul>			

Following that, a comparison table was created that analyses each tool based on the criteria described in Section III.A. An indicative section of the comparison table can be seen in TABLE II.

TABLE II. COMPARISON TABLE

Name	Version	Target users	Blockchain/ Transaction Records/	Personalisation	Semantics/ Interoperability/ Analytics/	Gamification	Qualification Certification/ Multilinguality	Recruitment/ Competency management	Open Source/ APIs
Qualification Check	Released	Businesses, public agencies, regulators, education providers, professional bodies, recruitment firms, HR teams,	No Blockchain Full audit trail and record for verification	No	No	No	Automated qualification verification, worldwide education verification, electronic transcripts/ degree certificates to outside bodies/ Multilinguality	No	QCheck API allows queries from integrated systems
Recognition Finder	Released	Students, job seekers	No	No	No	No	Allows users to see whether their professional qualifications can be recognised in Germany, not automatic, finds the competent authority/ 11 languages	No	No

The full table will not be presented in this body of work in its entirety, due to space limitations. However, the main purpose of the table was to help draw the conclusions that will be presented in the following section (Section IV).

#### IV. DISCUSSION

This section will conclude on the approaches that were analysed and the potential/projected position of QualiChain in the domains of Qualification Certification and Human Resource Management. The conclusions will be based on the eight criteria that were defined for the comparative matrix as well as the overall added value of the presented tools.

The target users constitute the only criterion where no significant differences among the various approaches can be noted. In fact, given that the tools presented are tailored for the stakeholders either in the domain of education, or that of the job market/HR management or a combination of both, it stands to reason that the target users are like those of QualiChain. Identified target users include students, job seekers, employers, private and public organisations, government agencies, education providers, regulators, HR teams and recruitment firms among others. This fact gives credence to QualiChain's approach for stakeholder identification and proves that the list of QualiChain stakeholders is as exhaustive and complete as it needs to be.

Moving on to other criteria, the analysis showed that only 4/19 (Blockcerts, Diplome, LinkChain, Blockchain for Education) tools take advantage of Blockchain ledgers and decentralised standards for the purposes of record keeping, issuing and verification of certifications. While, it is a fact that blockchains are harder to implement compared to more traditional databases, their capabilities for secure distribution of certificates, security, data privacy and immutability are considered to be of paramount importance for minimising fraud around educational and other certificates. Moreover, considering the approaches that did not use blockchain, only 2/19 (Qualification Check, DegreeVerify) keep any records of transactions and 1/19 (Vitnemalsportalen) provides any level of security by adding digital signatures on documents.

Concerning semantics and data interoperability approaches, of all the tools that were described, only 4/19 took it into account. Specifically, IT Staffing Nederland applies semantic software that translates ICT texts into digital e-competencies while Diplome applies other standards of interoperability on the data. On the other hand, Blockchain for Education, offers JSON-LD support which can therefore provide the required verification methodology. Furthermore, LinkChain is projected to be fully semantic and support public and private RDF. Moreover, 4/19 solutions had minor data analytics capabilities, mainly for the purpose of matching between a student's/ job seeker's profile and the skills required for a given position. Finally, 6/19 approaches provided some data structure coupled with searchable registries for the user's convenience. Such searches are only applied on static data and do not provide any automatic capabilities for analysis except for LinkChain that provides a federated searchable Linked Data Platform.

Another criterion studied, was the level of personalisation that each tool provides for a more user-centric experience. The results here are more encouraging given that 8/19 approaches provide some level of personalisation for a user's profile. For example, tools like ECTS make learning more user-centred via use of credits as currency. In addition, WES offers digital badges used to display verified credentials on social media sites like LinkedIn. Moreover, tools that are powered by the European e-Competence Framework, provide users with the capability to develop their profiles based on preferred orientation and competence gap analyses. Finally, the approaches that take advantage of Blockchain (Blockcerts, Diplome and LinkChain) provide each user with a valid and verified certificate/ qualifications wallet.

Concerning gamification, there are no tools that provide a clear solution. While there are some tools that provide some degree of informal gamification with credits and digital badges, the overall conclusion is that the community does not consider it to be that important for the developed tools. However, given that most of the tools are free of charge and offer solutions of low technical capabilities that are

realistically applied in Niche markets, it makes sense that gamification cannot be a priority in such systems.

The main criteria of the analysis revolve around the two main high-level functionalities that QualiChain will also provide, i.e., Qualification Certification and Recruitment/Competency Management. One clear division between the various tools, has to do with the level of automation that they provide. Only 4/19 solutions are non-automatic meaning that they do not automatically certify/validate users' qualifications but rather help them navigate through the various procedures that they will have to follow in order to get certified in a given country or domain.

The rest of the solutions provide various levels of automation and will be assessed based on the actual added value that they offer on the entire end-to-end procedure of either Qualification Certification or Recruitment/Competency Management. Starting from Recruitment/Competency Management, no tools were found that offer holistic solutions in a pan-European level. Specifically, while most solutions offer solid functionalities for organisations that can help their HR teams make staffing and strategic decisions, tools like NOKUT (Norway) mainly apply for their own country and other tools (e-CF 2.0 profiling tool, CEPIS e-Competence benchmark, e-Competences assessment and certification assessment and IT staffing Nederland) have application only for ICT positions and organisations. On the other hand, platforms like LinkChain do not directly offer such functionalities but support external analytics and can serve as a data backend for qualification analysis, opportunity identification, competency development & evaluation, etc.

On the contrary and concerning the domain of Qualification Certification, there are a number of solutions that provide added value in every step of the process. Tools like Qualification Check, ECTS, Blockcerts, Diplome, LinkChain and Blockchain for Education are holistic solutions that automatically handle every step of the process while some of them have been adopted by multiple countries. However, there are still solutions that are country specific (Vitnemalsportalen, DegreeVerify) that do not offer the full range of functionalities for every type of user (HEDD) and others like the ServiceNow module that offer micro-accreditations for expertise in specific platforms and tools. In addition, only five approaches support Multilinguality and only three of them (NOKUT, Diplome, LinkChain) offer functionalities for both Qualification Certification and Recruitment/Competency Management. One of the key suggestions of QualiChain is that having both services operate in a single platform seamlessly will further connect high-level education with the job market so that each domain can learn from the other and help students, job seekers and organisations make more informed decisions. Finally, the fact that 8/19 tools have APIs that allow them to connect with other systems can potentially help QualiChain synergise with them.

## V. CONCLUSIONS

The scope of this paper was to perform a state-of-play analysis on tools, applications and frameworks used in the

domains of Qualification Certification or Recruitment/Competency Management. All in all, most of the tools that were analysed are either commercial applications or country/domain-specific and are usually focused on specific functionalities that are useful in some steps of the processes required by students, job seekers, educational institutions and organisations of all types. This gives credence to QualiChain's holistic approach and proves that there is a vacuum on the market of the domains tackled by the project. In fact, not only does QualiChain aim to fill a void in the market but also to advance the state-of-the-art by developing a holistic platform that provides open semantic interoperability and data privacy by extending the research in blockchain, semantics, data analytics and gamification.

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# Decentralised Qualifications' Verification and Management for Learner Empowerment, Education Reengineering and Public Sector Transformation: The QualiChain Project

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**Abstract**—In today's society, formal and non-formal education credentials play an important role not only for holders of such diplomas and degrees but also for human resource management processes in public and private organisations. However, the degree of digitization in the sector is lagging, as certificates are still paper based and verification processes are very time-consuming. While the first Information & Communication Technology (ICT) solutions in these domains have been developed, they are still dependant on issuing organisations and manual processes. Blockchain is one technology that can be considered for developing trustworthy solutions for digital certificates, given its native characteristics for decentralisation, visibility and verification of transactions. Additionally, the computational intelligence found in analytics and decision support can help develop added value services while gamification can help develop more personalised approaches for the stakeholders of such domains. Under this context, the present publication presents QualiChain, an European Union (EU)-funded project that aims to revolutionise the domain of public education, as well as its interfaces with the labour market, policy making and public sector administrative procedures by disrupting the way accredited educational titles and other qualifications are archived, managed, shared and verified.

**Keywords**-higher education; public sector; certification; human resource management; blockchain.

## I. INTRODUCTION

In an era that every single piece of information around us is digitised and being exploited via innovative technological

solutions in a variety of value adding ways, education certificates are largely resisting the pull of technology, as they are still held in diverse formats in siloed databases, often involving time consuming manual processes for their verification [1]. In education, certificates confirm the achievement of certain learning outcomes and are until today mostly issued on paper or other physical formats [2]. Paper certificates have their advantages, such as being easy to store and difficult to forge due to built-in security features. However, they also create several issues, such as dependence from accrediting authorities for their issuing and verification as well as vulnerability to loss and damage [3]. Additionally, lying about education and employment credentials is a common problem, as it has become very easy to counterfeit academic diplomas and certificates, or even “buy” degrees from fake degree websites [4]. According to a survey by CareerBuilder [5], a staggering 58% of employers have caught a lie on a resume, whereas 33% of them have seen an increase in resume embellishments and fabrications. Similar findings arise from another survey by StatisticBrain [6], according to which over half of resumes and job applications contain falsifications and over three quarters are misleading. Under these circumstances, and although fraud is not limited to educational awards, trust in the educational certification system is receiving significant blows [7][8].

The aforementioned challenges create problems when education credentials are requested as a means of ratifying decisions regarding either personnel recruitment or individuals' further admission in other educational programmes. The recruitment of personnel by an

organisation is a lengthy process that comes along with combing through hundreds of candidates' résumés, weeding out the unqualified ones and narrowing down the rest into a group of potential recruits', whose qualifications and academic degrees have to be checked and validated on a case-by-case basis. These challenges do not limit to the actual task of recruiting but extend to a wider set of processes indicatively encompassing personnel allocation and re-allocation, staff mobility, and skills' development and evaluation, most of which fall under the notion of competency management.

Disruptive technologies, such as blockchain, algorithmic techniques, data analytics and semantics and innovative concepts like gamification may offer solutions to these challenges. Particularly, blockchain technology, as a decentralised, permanent, unalterable store of information can help with the archiving and trust issues, as well as provide a frictionless method for transacting with others [9] [10], whereas computational intelligence found in the technological domains of algorithmic techniques, data analytics and semantic analysis may facilitate decision making and optimise work practices and procedures. Moreover, gamification practices can help with user engagement and in developing a more user-centric solution. Under these circumstances, this publication presents QualiChain, a project targeting the creation, piloting and evaluation of a distributed platform for storing, sharing and verifying academic and employment qualifications that will focus on the assessment of the potential of the aforementioned combination of technologies for disrupting the domain of education.

Section I of this publication introduces the scope of the document and describes the challenges revolving around the verification of education certificates. Section II introduces the QualiChain concept and the high-level functionalities that it is projected to have. Section III describes the platform's architecture and introduces the pilot use cases, in which the platform will be applied. Finally, Section IV concludes the document.

## II. THE QUALICHAIN CONCEPT

QualiChain is a project that aspires to investigate and provide evidence on the transformative impact of disruptive technologies, such as blockchain, semantics, data analytics and gamification in the domain of public education, as well as the interfaces of the latter with the fields of private education, the labour market and public sector administrative procedures. The concept and focus of the project lie more specifically in the design, implementation, piloting and thorough evaluation in terms of benefits, risks and other potential implications of the QualiChain technological solution, a distributed platform targeting the storage, sharing and verification of academic and employment qualifications. At this point, attention has to be drawn to the fact that although originally inspired from the field of public education and the need to transform certificates' archiving and management, as well as to fight fraud around education awards, QualiChain concept has practically a much larger scope, as its services transcend the mere validation of

training certificates and bring forward solutions to major challenges of both public and private interest, such as those of lifelong learning, recruitment, mobility, better linking education with the labour market, etc., thereby accommodating the needs of several stakeholders (see Figure 1).

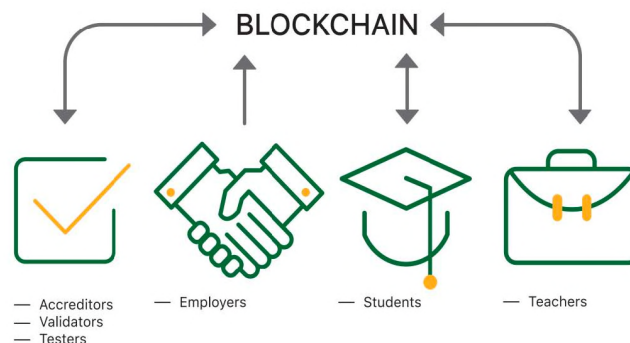


Figure 1. The value of blockchain to QualiChain stakeholders [3]

In fact, QualiChain services will be structured along two main pillars.



Figure 2. QualiChain Baseline Services

The first pillar (see Figure 2) will be grounded upon QualiChain main technological foundations, namely blockchain and semantics, enabling educational awards' and other qualifications' archiving and storing, awards' verification, the latter incorporating equivalence verification, as well as qualifications' portfolio management.





Figure 3. QualiChain Value Adding Services

The second pillar (see Figure 3) will build upon QualiChain baseline services to offer with the help of the computational intelligence, embodied in data analytics and decision support algorithms, as well as gamification techniques, a set of more advanced services, including career counselling, intelligent profiling, and competency management and within the context of the latter recruitment and evaluation support, and consulting.

### III. ARCHITECTURE AND PILOT CASES

#### A. QualiChain High-Level Architecture

QualiChain will deliver an open source solution, comprising of stand-alone components and an integrated environment to facilitate its adoption by the different stakeholders according to their needs. To deliver the services and functionalities prescribed in the QualiChain concept in the previous section, the envisaged QualiChain platform logic layer consists of 3 main components, namely a *Validation and Verification Engine*, a *Profiling and Career Management Engine* and a *Recruitment and Competency Management Engine*, composed in turn by 11 modules (see Figure 4).

The *Validation and Verification Engine* will be responsible for registering from scratch newly awarded certificates and achievements as well as for ratifying claims around the possession of certain awards and qualifications.

Thus, it will feature an *Awards' Registration Interface* that will enable issuing and accrediting organisations to register new verified qualifications' records in blockchain's distributed ledger, as well as a *Validation Query Builder*, through which all issuing institutions, public and private organisations, as well as individual users can set up appropriate validation queries. In greater detail, the Validation and Verification Engine is made up of the following sub-components: i. an *Equivalence Verification Module* that supports the identification and verification of equivalent degrees (or even skills, achievements and training courses), issued by different institutions, ii. a *Translation Module*, capable of translating certificates from one language to another, in case a both validated and translated version of a certificate is required, and iii. a *Credentials' Auditing and Verification Module*, responsible for accommodating new awards' registrations and thus adding new blocks to the blockchain database, as well as for receiving users' queries on the validation of awards and other qualifications.

The *Profiling and Career Management Engine* will be responsible for the functionalities required for the management of individual users' digital portfolio, aka digital learning ledger where the latter can archive and access their achievements, qualifications and work experience with the purpose of showcasing them to third parties. The specific component's functionalities are made accessible through a *Portfolio Manager Interface* and are brought to life with the help of the following modules: i. a *Verification Request Module*, enabling individuals to submit to accrediting organisations requests for the confirmation and formal verification of their achievements, ii. a *Career Advisor Module*, capable of crawling world wide web resources and applying data mining techniques with the goal of identifying and bringing into the individuals' attention job vacancies that match their profile, and iii. an *Intelligent Profiling Module*, that leverages job vacancies' elicited requirements and synthesises accordingly individuals' base profile information to deliver multiple, customised versions of their curriculum vitae.

Finally, the *Recruitment and Competency Management Engine* will include functionalities for competency management at both strategic and tactical level addressed to corporate users, the latter including not only education providing institutions, but also public authorities, private companies and policy makers. The Recruitment and Competency Management Engine exposes its functionality through the *Competency Management Advisor Interface* which makes up the entry point to the following sub-components: i. a *Recruits' Profile Designer Module*, enabling recruiters to designate the criteria that candidates should meet, and thereby specify the type and level education, work experience and the rest of qualifications that they should possess as well as any other conditions and requirements they ought to fulfil, ii. a *Qualifications' Screening and Matching Module*, capable of retrieving

applicants' credentials and juxtaposing these with recruiters' criteria to sort out a subset of appropriate candidates, iii. a *Selection and Recruiting Module*, applying advanced decision support algorithms on the subset of qualified candidates, to optimise candidate selection and allocation in corporate positions, iv. a *Competency Development, Evaluation and Gap Identification Module*, responsible for keeping track of employees' qualifications records and

identifying competency deficit in relation to organisations' mid and long-term horizon goals and v. an *Advanced Decision Support Module*, featuring a variety of sophisticated data analytics, i.e., data mining, statistics' calculation, pattern/ trend recognition, data visualisation and other functionalities of both descriptive and prescriptive character, to support insights acquisition and informed decision making.

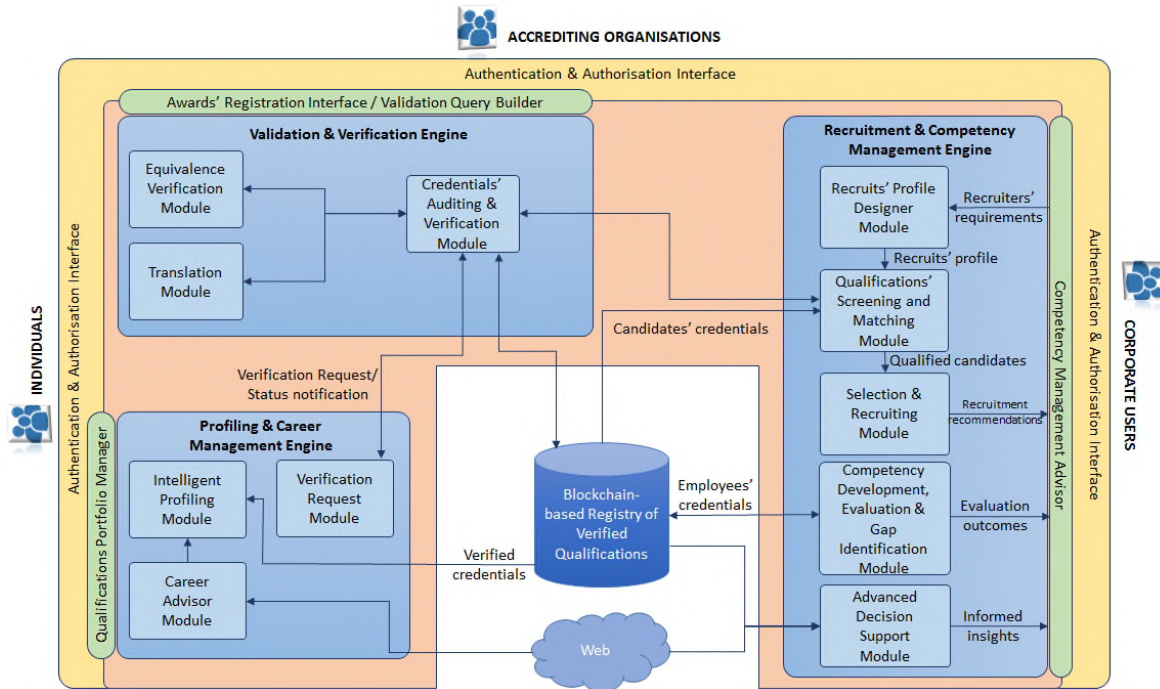


Figure 4. QualiChain Value Adding Services

From an end-user perspective and regarding the QualiChain platform presentation layer, the solution lays emphasis on intuitiveness and features beside the aforementioned management interfaces, appropriate authentication and authorisation interfaces for all targeted stakeholder groups, namely accrediting institutions, individuals and corporate users. Finally, the QualiChain data access layer envisages storage and retrieval of data from blockchain records regarding awards and qualifications, as well as from the web to the extent related statistics, job postings and other learning and career development opportunities are concerned.

### B. QualiChain Pilot Use Cases

To test and validate the projected platform in its respective domains, it will be implemented in four distinct pilot use cases split between academia, private and public organisations. Specifically, the QualiChain pilots are the following:

#### 1) Cross University Degree Equivalence Verification

Within this pilot use case, QualiChain will develop a methodology for representing the semantics of educational

credentials, to support cross-institution and cross-context mapping between different forms of certifications. Existing vocabularies that describe learning goals and topics will be reused and extended to build a detailed knowledge model describing the entities relevant to educational accreditation and their relationships to each other, in the form of an ontology. This pilot will engage lifelong learners, students, job seekers and educational institutions.

#### 2) Smart Curriculum Design and University Process Optimisation

This use case will be implemented in the School of Electrical and Computer Engineering of the NTUA. It will take advantage of QualiChain's analytics and decision support capabilities to analyse the current skill level of students, the school's curriculum and the labour market's requirements for the school's graduates to provide decision support for optimising the school's curriculum. Additionally, this pilot will leverage the blockchain ledger to verify student skills and qualifications with smart badges. This pilot will engage undergraduate and Ph.D. students of the school as well as professors and administrative bodies.

### 3) *Staffing the Public Sector*

This pilot use case lies in using the QualiChain platform and services for supporting and simplifying public sector recruitment and competency management procedures. Given that recruitment in public administration must be based on the principles of impartiality, transparency and fairness, this pilot will leverage the platform's blockchain to manage and verify the applications and other supporting documents submitted by candidates. Additionally, the recruitment and competency management services of QualiChain will be used to automate applications' checking and candidates' assessment and selection procedures, and respectively for supporting decisions related to the allocation of human resources within the public sector or employee mobility issues. This pilot will engage public administrations, recruitment firms, employees, job seekers and issuing organisations.

### 4) *Provision of HR Consulting and Competency Management Services*

This pilot will explore blockchain for easily checking and ensuring the availability of certain competencies in an individual curriculum. Also, data analytics methodologies and algorithms will be applied for the effective matching of skills, qualifications and competencies with job description requirements, not only for external selection, but also for internal mobility. Semantic technologies will be used to support corporate training and carrier management, throughout the entire individuals' job evolution. This pilot will engage public entities looking for new applicants, candidates and public workers.

## IV. CONCLUSIONS

This publication presented QualiChain, a project aiming to develop a decentralised platform for storing, sharing and verifying academic and employment qualifications. Despite the fact that the project is still at an early stage, it has gathered the interest of the research community due to the innovative combination of technologies that it will leverage and the fact that it aims to create value to all stakeholders in the domains tackled. This is also reflected in the complexity of QualiChain's technical solution and the number of distinct pilot cases in which it will be implemented. The innovation potential of QualiChain is very strong, as it focuses on a domain, that of education credentials, that has largely resisted the pool of technology and where the improvement potential in the processes of certificates' archiving, management and verification, the information flow amongst stakeholders and the opportunity for offering

value adding services on top of the aforementioned processes and developing new business and education models is literally huge. Disrupting any (or even more than one) of the aforementioned aspects can lead to substantial efficiency, productivity and transparency impacts, which should in turn have noticeable positive societal, economic, political and cultural effects.

## ACKNOWLEDGMENT

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# Towards A Blockchain-based Decentralised Educational Landscape

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**Abstract**—Institutions in the current educational landscape operate independently. They exhibit reluctance in sharing their teaching and qualifications with others due to the fear of damaging individuality. This practice, however, is counterproductive for the students as they suffer from various difficulties and get deprived of certain benefits. In this paper, we explore the possibility of finding a solution to this deadlock. We argue that Blockchain-based decentralisation can offer a passageway where educational institutions get to keep their individuality but participate in collaborations to help overcome the problems students face. Our principal contribution in this paper is a conceptual educational landscape to show how institutions could potentially manage record-keeping, credential verifications, and continued career support in a decentralised environment.

**Keywords**—*blockchain; decentralisation; verification; education.*

## I. INTRODUCTION

The primary role of educational institutions is to offer governance, teaching, qualifications and support towards a successful career of their graduates in the post-study period. In this practice, they exhibit a standalone, scattered and remote model. They do not show interest in sharing their teaching methods or qualifications with others due to the fear of damaging their goodwills and reputation. The roles of the institutions can also vary broadly. Some provide both tuition and degrees while others only teach and the degree comes from issuing authorities who do not offer teachings. The practice of universities issuing qualifications for other institutions having no right to confer the degree on their own is not rare either. In addition to maintaining their individuality, the complex nature of types and roles heavily contributed against decoupling educational institutions from their standalone model, making the education system inherently isolated.

This current model is inadequate, backdated and sometimes damaging. It cannot see the full academic history of a student; hence, institutions fail to act appropriately. This model is also unsupportive towards lifelong learners and students receiving micro-credentials. Amongst many shortcomings, the following are three prominent problems that students frequently encounter. First, students need to verify their qualifications every time they join a new job or a new course, which is time-consuming and expensive. Second, the centralised governance puts students records in danger as such practice increases the chances of corruption, manipulation and privacy violation. Third, and finally, institutions fail to give adequate career

support, particularly for a more extended period when students achieve multiple qualifications from more than one institution.

While a universal institution is not a practical concept, students' miseries are genuine intricacies that need solving. In this paper, we show that employing Blockchain technology can help decentralising qualification verification, data governance and career support. We demonstrate how existing technologies and methods can be put together to offer a reasonable solution to these problems.

The remaining paper is organised into six sections. Section II presents the current educational landscape and identifies the problems, Section III reviews the technologies to be used in the proposal and Section IV describes potential decentralisation models. Finally, Section V presents the proposed Blockchain-based decentralised educational landscape before concluding the paper in Section VI.

## II. CURRENT EDUCATIONAL LANDSCAPE

Historically, education is an isolated system centred around teachers or teaching schools [1]. Before the establishment of formal institutions, pupils used to go to teachers' homes to receive an education. This practice gradually evolved, and both pupils and teachers started to gather at common locations, often at renowned places. This move began to establish the concept of school, although still not as a formal institution [2]. Raphael's celebrated fresco the School of Athens on the wall of Apostolic Palace in Vatican City is an excellent depiction of how the school used to look like in the ancient period (shown in Figure 1). Ancient Greece, Ancient Rome, Ancient India and Ancient China have well-documented histories of such schools [3]. By the time the University of Bologna opened its door to students in Europe roughly a millennium ago, the need for institutional education had echoed at different places across the continent and the universities of Paris, Oxford and Cambridge were established.

In this journey of evolution from teachers' home to formal institutions, one element remains common – the standalone and remote nature of the institutions. There are many lobby groups and collaborations between institutions for promoting their names and values, such as Ivy league (US), Russell Group (UK), U15 (Canada), G8 (Australia), Coimbra Group (Europe) and so on, but not many initiatives in giving joint teaching and degrees. Educational institutions have always been protective to safeguard their reputation as they fear sharing teaching





Figure 1. Raphael's celebrated fresco the School of Athens on the wall of Apostolic Palace in Vatican City.

practice and qualifications with others might put their goodwill in danger. Even institutions of the same status can have severe reluctance in joining such a union [4]. For instance, Imperial College London and University College London, two world-renowned universities from England, initiated a merger in a bid to form a large university capable of attracting twice the research fund universities such as Oxford or Cambridge can allure [5]. Although the alliance could help them achieve many benefits, it did not come through due to opposition from management and students of both universities [6].

In the present days, educational institutions play a broad role. Some provide governance, teaching, qualifications and career support. In contrast, others may provide a subset of these duties, such as awarding bodies confer qualifications while institutions without the right of giving their own degree contribute in teaching and governance. With the rise of the World Wide Web, online-based education and micro-credentials have recently become popular. Most of these qualifications come from distance learning and online institutions. The size and functional scope of these institutions are limited, making them provide slow verification assistance and almost no career support in the post-study period.

The current educational landscape shows us the practice has three broad problems. These are as follows:

#### A. Problem P1

It is a common practice that all educational institutions maintain individual databases of their own to store and hold students' records including their personal information. In most cases, students have no or limited control over their data and often remain oblivious to what exactly their institutions keep on their behalf. This centralised approach, in general, has been a subject of mounting concern as social awareness surrounding how users control their data continues to grow. Such an approach can cause alteration of data for numerous reasons including updates by mistakes, corruption and most importantly deliberate manipulation by the controlling administrators leading to tempering or removal of data without the owner's

consent or knowledge. Privacy could be another solicitude as data can be viewed, shared or sold by the possessors.

#### B. Problem P2

Educational institutions maintain an old tradition of carrying trust through badges, diplomas and certificates. It used to work when there were fewer institutions, and people recognised the certificate issued by a specific university or school. However, as time passed by, people started to lose faith in paper certificates due to the availability of handy technology that can produce fraudulent documents. Instead, it became a new trend for the bearers of certificates, transcripts and other educational records to establish the authenticity of their papers. Sometimes they need to send documents to another school or an employer using official email of the providers, while some test scores, such as the International English Language Testing System (IELTS) or Graduate Record Examinations (GRE) need to come directly from the issuers by post. What seems to be the biggest irony in the education sector is that even the educational institutions that once proudly developed the convention of issuing certified documents now do not trust them and ask for verification at the time of admitting new students.

#### C. Problem P3

The existing education system is mainly scattered, where educational institutions operate standalone failing to provide continued career support for their students. There indeed exists a practice of helping current students and alumni to obtain jobs through arranging networking sessions in universities and colleges. Still, the impact of such events is limited, and the process lasts for a few years in the post-graduation period. Furthermore, institutions generally have access to records and degree information of the qualification they provide only and cannot access or verify their students' skills and diplomas obtained from other institutions. This limitation prevents them from adequately assessing one's potentials and helping them to apply for the right job and guide them to their career paths.

### III. TECHNOLOGY REVIEW

While forming alliances amongst the universities sharing their student records, teaching, and qualification does not seem practical under the current landscape, the problems P1, P2 and P3 desperately need solving. We, therefore, argue that it is time to look for a resolution elsewhere and propose a solution in this paper using existing technologies, such as Blockchain, distributed storage and linked data. Before we present the explanation of how these technologies offer the answers to the problems, we introduce them briefly below.

#### A. Blockchain Technology

A Blockchain is an immutable distributed ledger secured by cryptographic techniques, as shown in Figure 2, and managed by a decentralised community over a peer-to-peer network through incentivisation [7]. Each member of the community is commonly known as *node* who distributedly maintains the storage of the Blockchain. No node has the authority to make changes unless agreed by the majority of the network. The process of this agreement is called *consensus* [8].

The transactions of a Blockchain are called *immutable* because once inserted, they become permanent and cannot be

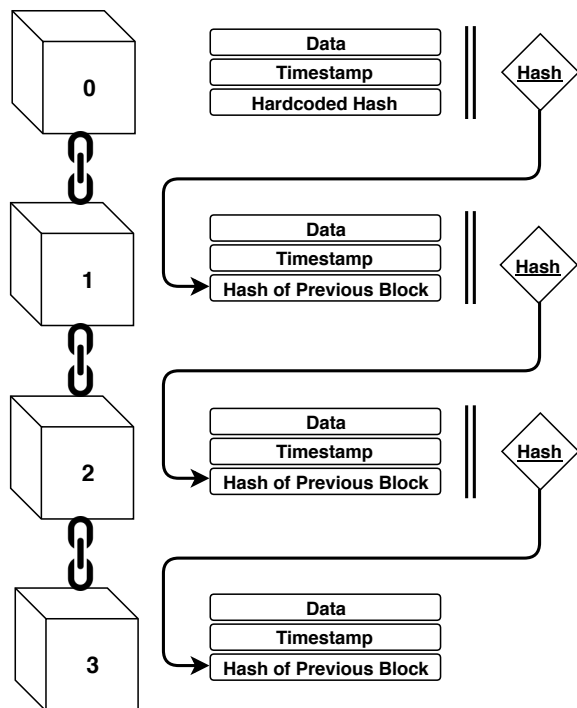


Figure 2. Each block in a Blockchain is chained to one another using cryptographic hashes creating the ultimate bond to develop the chain.

modified retroactively, not even by the authors, without the alteration of all subsequent transactions. The first block of the chain is called genesis block with subsequent blocks added through consensus between nodes. Various consensus methods, such as proof of work, proof of stake, proof of authority etc. are used in different protocols that allow nodes to compete for a pole position enabling them to insert the new block. The design of a Blockchain ensures that, once entered, contents of the blocks cannot be changed as long as no entities control more than 50% of the nodes. This property of Blockchain makes it trustworthy.

The progress in the development of Blockchain has taken the technology beyond the storage of records and includes distributed computing in the form of smart contracts. These are blocks of executable source code stored on a Blockchain with a published interface describing the methods and their parameters. The code gets executed when the corresponding transaction is added on the distributed ledger. Because the code fulfils the same requirements of the immutability of Blockchain data, smart contracts form trustworthy distributed computation [9].

### B. Linked Data

Linked Data is a form of structured data interlinked with other data to become useful through semantic queries of associative and contextual nature. It extends the capability of Web data originally meant for only human readers to share information in a way that can be read automatically by machines [10]. Linked Data plays a vital role in integrating data in the presence of multiple data sources, making them interoperable.

Sir Berners-Lee, the founder of the World Wide Web, first coined the term in his note Linked Data. He also outlined four

principles known as four rules for Linked Data. These rules state that Linked Data, i) Uses Uniform Resource Identifiers (URIs) as names of things, ii) Uses HTTP URIs to look up those names, iii) At the time of looking up a URI, provides useful information using the standards, such as Resource Description Framework (RDF) and SPARQL [11], and iv) Includes links to other URIs to discover more things [12].

### C. Distributed Storage

Distributed Storage is a decentralised approach of storing data in one or multiple servers. HyperText Transfer Protocol, or more commonly known as HTTP, is considered the biggest distributed database where peers can access particular data from anywhere in the world. HTTP became outdated due to its centralised nature. Peer to Peer (P2P) file system, such as BitTorrent, took its place. Although BitTorrent comes with a lot of advantages, several drawbacks, such as unstable downloading, unverified publisher and a lack of incentive mechanism restricted its use [13].

After the arrival of Blockchain, a combination of the distributed file system and Blockchain becomes a promising solution where the former provides the storage facilities while the latter ensures the integrity of the data and provides a way to achieve incentives. Interplanetary Filesystem (IPFS) [14], Swarm [15], and FileCoin [16] are some of these modern distributed storages.

### D. Solid: Social Linked Data

Sir Berners-Lee originally viewed the World Wide Web as a decentralised network. It was close to a peer-to-peer network assuming each user of the Web would be an active editor and contributor, creating and linking content to form an interconnected web of links [17]. The Internet, however, gradually turns out to be the opposite - an ideal example of the centralised paradigm. Sir Berners-Lee's response to this evolution of the World Wide Web is Solid. Solid, derived from **S**ocial **L**inked **D**ata, is a set of rules and tools for developing decentralised social applications based on Linked Data. It uses as much as possible the existing W3C standards and protocols [18].

Solid aims to modifying the centralised client-server paradigm, improving peer-to-peer networking in a manner that adds more control and performance features than its traditional concept, such as BitTorrent. Its central focus is to enable the discovery and sharing of information in a way that preserves privacy. It allows users to store personal data in Pods (Personal online data stores) hosted at the location of users' desire. They also have the flexibility to distribute data among several pods; allowing them to organise various types of data (personal, contact, health, financial) in multiple pods with varying degree of access control. In a nutshell, Solid allows users to retain complete ownership of their data, including where to store the data and who has permission to access it [19].

## IV. DECENTRALISED MODELS

Disintegrating educational institutions from their isolation does not necessarily have to come through sharing teaching or credentials. Decentralising their governance can potentially make them open to the authorised parties who can access information without any formal union. This approach establishes a trade-off where institutions get to keep their individuality

but participate in collaborations to help overcome the existing problems.

Decentralisation means the transfer of authority from one or more central controlling body to local representatives – in the context of web technology, these representatives are generally users. In an educational landscape, the institutions act as the central controlling bodies while students are users. Decentralisation gives students the authority over their data. They get to decide the storage location of their data and can grant access to specific entities while disallowing such access to others. There are several ways to achieve decentralisation. The following describes three models that can be used to decentralise the educational landscape.

#### A. Model M1: Pure Blockchain-based Decentralisation

Blockchain is decentralised by nature and a distributed ledger that can be used as data storage; hence, it acts as a useful tool for decentralisation. By design, data on a Blockchain are immutable; therefore, no further actions are required to ensure data integrity. There are different ways available to store data on Blockchain. The most efficient way of storing data on a Blockchain requires a smart contract. This model provides a fully distributed storage with a firm guarantee of data integrity. The tradeoff is, however, the cost as it requires payment for every contract deployment. The cost varies based on the size of the smart contract; the longer the contract, higher the fees required to deploy it. Amongst other shortcomings, lack of privacy is one that hinders its useability significantly. Besides, there exists various types of Blockchain, and depending on their kinds, advantages and disadvantages may differ. The following describes three major Blockchains, public, private and consortium, and their suitability.

1) *Public Blockchain (M1-A)*: A public Blockchain has absolutely no access restrictions. Anyone with an Internet connection can act as a participating node or send transactions. For a public Blockchain to keep operating, the platform provides some form of economic incentive or reward, often in the way of giving away some native currency, but it can be fees too.

A public Blockchain is more trustworthy due to being managed by a large community where no one has particular superiority over others in its governance and decision making. Nevertheless, it is not privacy-friendly due to being always open. This feature allows anyone to read its contents unless encrypted. Public Blockchains are expensive and storing and accessing data on this type of Blockchain can incur huge fees. In general, Blockchains do not come with built-in searching mechanisms, rather applications require developers to implement their own search functionalities. This inefficacy meets with another problem in public Blockchains. Their contents grow very fast, making the search even more difficult.

2) *Private Blockchain (M1-B)*: A private Blockchain is one that a single entity controls. Participating nodes require permission to join a private Blockchain and may have limited privileges. Because of access restrictions, private Blockchains offer some degrees of privacy and they do not grow as fast as public Blockchains. A big advantage of using private Blockchains is that they do not require *real money* to store and access data. However, they are not entirely trustworthy. The entity that controls their governance and operations may retain a superior power for tempering data.

3) *Consortium Blockchain (M1-C)*: A consortium Blockchain can have the best of both public and private Blockchains. It is sometimes referred to as a shared ledger or federated ledger because of multiple approved parties using it within a federated environment. These Blockchains are private Blockchains operated by a group or consortium and usually require permission. However, instead of a single body controlling it, various organisations can share governance. The administrators of a consortium Blockchain may restrict users' reading rights and allow a limited set of trusted nodes to execute the consensus protocol.

The main advantage of consortium Blockchains is they can bring the best of both public and private Blockchains. Because of having access restrictions (as only invited, and approved entities can join the Blockchain), they are more privacy-friendly than a public Blockchain. Besides, unlike a private Blockchain, a single entity may not hold control of the consortium Blockchains, making them more trustworthy. However, consortium Blockchains can still be vulnerable. Their number of controlling authority is likely to be limited, making it possible to group and launch 51% attack quickly [8].

#### B. Model M2: Distributed Storage-based Decentralisation

Potential decentralisation strategies using distributed storage include two possible routes. The first is solely based on distributed storage, while the second option uses a combination of distributed storage and Blockchain.

1) *Distributed Storage Only (M2-A)*: Data can be distributed across multiple servers by duplication with anyone wishing to use the desired copy must know its precise location. This approach, however, fails to ensure the integrity of the data as there remains no straightforward way to identify if the data is altered. An improved method could be making the distributed storage to act as a filesystem for storing data with clients keeping copies of hashes of all files locally. Clients can then run the queries with these hashes to retrieve the data (e.g., IPFS). This technique helps to verify the integrity of the data because if the stored data gets altered, there will be a mismatch between the locally stored hash and the hash of the data, tearing apart the connection. In such cases, clients' query does not return the altered data, and in the event of no results, we can assume that either the data got tempered or went missing [20].

2) *Distributed Storage and Blockchain (M2-B)*: Instead of using distributed storage alone, another approach is to incorporate a Blockchain in the management of the data [21]. This use of a distributed storage with Blockchain can help to reduce the cost encountered while using pure Blockchain-based decentralisation. This model makes the decentralisation cost-effective but incorporates guaranteed data integrity. It also enables clients to avoid the need for maintaining the hashes locally; instead, data goes to a distributed storage while hashes and their associated timestamps stay as a trustworthy record on the distributed ledger [23].

#### C. Model M3: Solid-based Decentralisation

Solid can offer a third route to decentralisation. Solid pods are decentralised and give users full control of their data. They also ensure privacy as only approved entities can read and



access the data. There are two possible ways Solid can be used, standalone or in combination with a Blockchain.

1) *Solid-only Decentralisation (M3-A)*: The use of Solid is sufficient to introduce decentralisation. The ability of users while using Solid to store various types of data, such as personal, financial, educational, health, and so on, in different Solid pods makes way for creating customised privacy control. Users may give certain entities access to their personal and educational data but restrict access to financial and health data while using Solid. A significant shortcoming of Solid-only decentralisation is trust. Because of users having full control over their data, they can modify them anytime. Third parties having to rely on user data can find this model less prudent.

2) *Solid and Blockchain (M3-B)*: The use of a Blockchain with Solid pods is a type of decentralisation where Solid holds the data while a hash of it goes to the Blockchain, ensuring the integrity and trust of the user-controlled stored data. This strategy brings all the benefits that a Solid-only model can offer and solves the trust issues. Because a hash of the data goes to the Blockchain, third parties can quickly check the integrity by hashing the data stored on the pods and matching it with its Blockchain counterpart [22].

## V. PROPOSED EDUCATIONAL LANDSCAPE

In decentralising the educational landscape, we propose a four-layer architecture where Blockchain forms the first layer from the bottom. The design embraces three other layers on top of the Blockchain layer, namely data layer, verification layer and support layer – Figure 3, shows the architecture and the arrangement of the layers in the design.

Three problems, P1, P2 and P3, that we identified in Section 2 represent three broad areas of the educational landscape and form the top three layers in our design. P1 represents data management and governance and creates the data layer, P2 focuses on the credential verifications and forms verification layer, and finally, P3 states the continued career support for the students and produces the support layer.

### A. Blockchain Layer

The Blockchain layer forms the foundation of our proposed architecture. We recommend using a consortium Blockchain due to its ability to mimic the best of both private and public ledgers. In our architecture, participating institutions will join and govern this consortium Blockchain. The remaining three layers will operate over the Blockchain and will have the ability to access it directly or through other layers.

### B. Data Layer

The second layer in our architecture is the data layer responsible for data governance. It manages students data in a decentralised style. Institutions generally maintain a central database to hold all kinds of data, including students records and information. Data layer disintegrate this database and distribute its contents to various stakeholders, such as students, teachers and administrators. Amongst the suitable decentralised models, M1-C, M2-B and M3-B from Section IV look useful for developing this layer. However, due to lack of privacy, M1-C does not fit for sensitive data like personal information, students record and results; therefore, we prefer M2-B and M3-B, which means storing data on either IPFS or Solid with their hashes on the Blockchain. Between

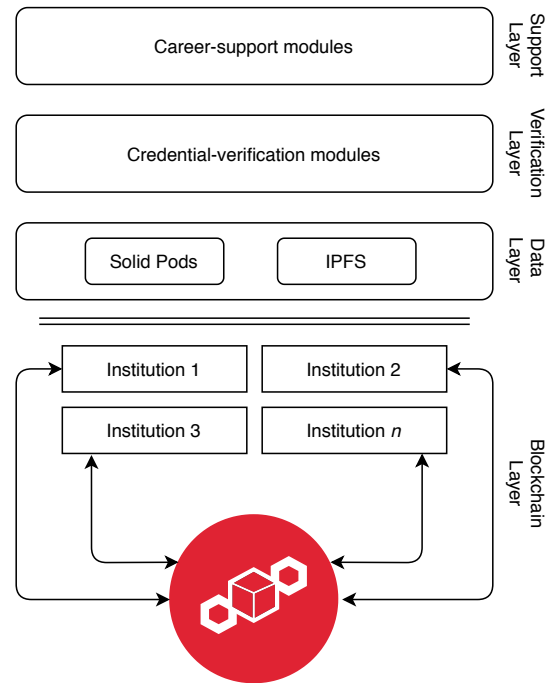


Figure 3. The layered architecture of the Blockchain-based proposed decentralised educational landscape

these two models, Solid offers added benefits in the form of advanced access control; hence, we use Solid while describing the remaining architecture.

The data layer consists of Solid pods managed by students, teachers and administrators. Students will have their personal information on their pod that they grant access to only their institutions. Administrators of the institutions can have some student data on their pods too, such as results and qualifications. In this case, they grant at least read access to students so that they can be aware of what data institutions hold on their behalf. This access may be time-dependent; for instance, results data will be made visible to students only when the results are announced. Teachers can have their pods to store and share students marks and initial results. They may only grant access to this data to administrators before the results are finalised. Institutions should have specific policies tailored to their practice concerning when to share data and how.

In a decentralised architecture, multiple sources can hold the data making it difficult to run queries using traditional methods. Linked Data and federated query can help to solve this problem. It works as follows: Each and every entity in a Solid pod are represented in the form of URIs. If the data stored in the Solid pods are expressed in RDF format, it can be queried using SPARQL, which is a query language for accessing linked data [11]. SPARQL can also be used to query data from multiple Solid pods as long as the query engine is granted access to the Solid pods [20].

The data layer solves P1. It gives students control over their data and allows them to see what their educational institution holds on their behalf. By employing Blockchain, data layer also ensures the integrity of the information contained by students and administrators.

### C. Verification Layer

The verification layer is responsible for verifying credentials. This layer helps students and lifelong learners to get their qualifications checked for potential employers and other educational institutions. All institutions that confer degrees or award micro-credentials must give students a badge or similar object that students keep in their Solid pods. Later at the time of applying for courses in other institutions or jobs in companies, they show the badge as a representative of their qualification certificate.

Badges are digital objects that students can temper. Therefore, to ensure the integrity of the data, issuing authorities insert hash of the issued badge to the consortium Blockchain. They also keep a record of the credentials to their Solid pods with students having access to it. An entity wishing to verify a particular credential does not have to go to the issuing authority. Again, Linked Data and federated query help us achieve this. The verifier can be a web application which seeks access to a Solid pod stored qualification badge, which then hashed by the web application. The badge hash is compared with the hash stored on the Blockchain which was previously uploaded by the badge issuer. If it matches, then the employer knows that the student badge is valid [24].

The verification layer solves P2. By making verification automated, it allows students to get their credentials verified at the expense of a few mouse clicks. It reduces time and saves money for both students and parties who check their credentials.

### D. Support Layer

The support layer paves the path for both educational and non-educational institutions to participate in providing career support to students and lifelong learners. These supports can come in various ways, including suggesting jobs, courses and preparing automated CVs.

Our architecture already showed how data are made accessible for approved entities through Linked Data and federated query engines. Educational institutions can run federated searches on the available job and qualifications of their graduates to pinpoint suitable employment for them. Potential employers can also benefit from this decentralised architecture as they can shortlist potential candidates on their own through verified qualification matching. Educational institutions can further suggest courses to students based on the qualifications they do not have but would help them land their preferred jobs. Institutions and commercial companies providing HR support can also use the data to offer students smart resumes where verified credentials and job information will be appended automatically.

The support layer solves P3 by opening data to approved parties. In a centralised and isolated system, educational institutions cannot see what qualification students have in addition to theirs. In this proposed architecture, institutions do so; hence can come up with job and course suggestions more precisely.

## VI. CONCLUSION

Educational institutions behave like islands – isolated and remote. Their reluctance in sharing teaching and credentials create sufferings for the students. In this paper, we try to find a trade-off proposing a decentralised educational landscape

where institutions do not have to lose their individuality but can still participate in collaborations. Using existing technologies, we showed how record-keeping, credential verifications and continued career support could be provided in a decentralised atmosphere.

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# Digital Transformation of Education Credential Processes and Life Cycles – A Structured Overview on Main Challenges and Research Questions

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**Abstract**—In this article, we look at the challenges that arise in the use and management of education credentials, and from the switch from analogue, paper-based education credentials to digital education credentials. We propose a general methodology to capture qualitative descriptions and measurable quantitative results that allow to estimate the effectiveness of a digital credential management system in solving these challenges. This methodology is applied to the EU H2020 project QualiChain use case, where five pilots have been selected to study a broad field of digital credential workflows and credential management.

**Keywords**—*Credentials; Education credentials; Digitisation; Challenges in digitisation.*

## I. INTRODUCTION

Education credentials are an important part of our modern life. Pupils exit schools with a set of marks certified on their final school report, then, based on these results, they are able to apply for acceptance at higher education institutes or for apprenticeship. Students and employees continue to collect credentials at university, at work or via other ways of education. Even today, when digitisation has entered into almost every part of our lives, these education credentials often still are printed and written on paper. These paper-based credentials present several problems in practice. For example, managing of these credentials applying for a job position is tiresome for the applicant and even more so for the company that offers the position. Indeed, most companies nowadays require scans of the paper credentials and will only check the validity of the originals once the candidate for the position has been selected, to avoid the manual labour involved. Additionally, surveys show that lying about education and employment credentials is a common problem. According to a survey by CareerBuilder [1], 58% of employers have caught a lie on a resume. Similar findings arise from another recent survey by StatisticBrain [2], which reports that over half of resumes and job applications (53%) contain falsifications and over three quarters (78%) are misleading. Digitisation of education credentials has the potential to make credential handling both easier and more secure. Nevertheless, it is important to ask the correct questions to be able to investigate how well a solution performs in the implementation and management of digital education credentials.

The main contribution in this work in progress article is to present the main challenges encountered in education

credential management and usage, and in the changes from analogue to digital credential workflows. We propose specific questions that will allow an qualitative and quantitative assessment of the performance of a credential management system and infrastructure in regard of these challenges (given in Table I). Finally, we introduce the use case of the EU Horizon 2020 project QualiChain [3], where these research questions will be evaluated with the help of the participants in the project's pilots.

The article is organised as follows: In Section II, we elaborate the different challenges we encountered while analysing the reports and questionnaires provided by the QualiChain pilots. In Section III, we propose a set of questions for every challenge presented in the previous section. In Section IV, we present the use case of QualiChain. The article closes with Section V where our conclusions and future work are outlined.

## II. CHALLENGES IN EDUCATION CREDENTIAL MANAGEMENT

How can the performance of a solution offering the issuing, management and verification of digital education credentials be evaluated? Based on the results acquired in [4], we propose to segment the questions of interest into three subtopics, that follow the process of changing from an analogue to a digital setting:

- A. *Challenges of paper-based credentials;*
- B. *Challenges of transition to digital credentials; and*
- C. *Challenges of digital credentials.*

In the following sections, we present these experienced difficulties and propose ways how to measure the performance of a presented solution for the implementation and management of digital education credentials.

### A. Challenges of Paper-Based Credentials

Paper-based credentials are the state of the art and have a history dating back to medieval times. Their use over centuries makes it obvious that, before digitisation, they were widely seen as the best solution. However, the developments in the last decades and the move to digital workflows increased the pressure on analogue, paper-based credentials and lead to increasing problems, especially in the field of fraud prevention.

1) *Fraud and Verification*: Advances in digital printing make it continuously more difficult to protect paper-based credentials against fraud. As already mentioned, a survey by CareerBuilder [1] reports that 58% of employers have caught a lie on a resume and 33% of them have seen an increase in resume embellishments and fabrications like embellished skill sets (57%), embellished responsibilities (55%), dates of employment (42%), job titles (34%), academic degrees (33%), companies worked for (26%) and awards (18%). A different survey [2] states that over half of resumes and job applications (53%) contain falsifications and over three quarters (78%) are misleading. Most issuers do not have the capabilities to use advanced falsification protection in their paper credentials, compared to what is done, for example, for paper-based money. Without a general standard, it would also be impossible for a non-expert to decide if the credential in front of him/her has the correct characteristics, as there are over 3000 higher education establishments in the European Union alone [5]. Instead, institutions and states commonly register important credentials and allow interested individuals to inquire on the validity of a presented credential. The UK, for example, offers the Higher Education Datacheck service [6]. The use of this service is chargeable, and the process can take up to seven days [7]. The process is also highly manual and time consuming.

2) *Dependence on Issuer*: The problems with fraud make it difficult for other than official education establishments to issue education credentials. This leads to the problem that learners will be unable to furnish sufficient and incontestable proof over several types of qualifications gained outside this established system. In the job market, written recommendation statements (also easy to falsify) or contact persons of reference are used to compensate for this. These methods are also manual and time costing for the people involved. The challenge to correctly identify the issuer of such as statements is related to this problem. Additionally, this can be the reason why direct access to reference persons often is preferred, as in this case the authenticity of the reference person can be checked by other means, like contact over official phone numbers or email addresses.

3) *Handling*: Paper-based credentials are easy to handle and store for the bearer, but in situations where many credentials have to be collected, screened and analysed, the high manual handling costs make their use expensive. This leads to a time consuming and costly recruitment process. For staffing private and especially public sector organisations it can be challenging to efficiently handle competency management in large organisational structures, as was reported in our questionnaire collection at the QualiChain pilots.

4) *Data Security*: Using high-quality acid free paper and storage in low humidity and at room temperature in pest free environments, paper has successfully been archived over many decades. Additionally, data protection can be enforced by physical access restrictions that are commonly available. However, most users of paper-based credentials outside of official archives and libraries lack the means of long-term storage, which makes paper-based credentials vulnerable to loss and damage. This is made more severe by the impossibility to create identical copies of paper-based credentials.

## B. Challenges of Transition to Digital Credentials

Any solution that asks users to move from a well-established analogue paper-based workflow to a digital workflow, will face challenges in this transition. In the following points we present the issues we encountered in our data collection.

1) *Digitisation of Existing Credentials*: Analogue credentials are put into existence using written text, images, drawings and security characteristics in various forms. To retain all this information in digital form is difficult, and to efficiently work with the content of the credential, it is necessary to convert the unstructured text, for example gained by a scan of the document, into structured data, that has been semantically enriched.

2) *Interaction Between Analogue and Digital Workflows*: While workflows for both digital and analogue paper-based credentials exist, it is desirable to cater for both types, if technically feasible and sensible. Often this will mean making manual adjustments possible in a digital workflow or to temporarily create digital twins of paper-based credentials to incorporate them into pure digital workflows. This can also mean that digital credentials are printed out, to be included in paper-based credential workflows.

## C. Challenges of Digital Credentials

Digital representations of credentials have their own challenges, that may be quite different from the paper-based ones.

1) *Private Data Protection*: Digital data can easily be copied, and creating identical copies of digital data is part of the normal workflow in IT. If, for example, a digital credential is sent from the issuer over a secure channel to the credential holder, its actual data is copied multiple times in the process: The credential is copied from the data storage at the issuer to the network stack of the issuers system, then copied into a transport format, copied over various relays in the communication system till it is copied once more into the network stack of the receiver, unpacked and finally copied into the receiving application's memory. However, this characteristic of digital data makes it also easy to leak private data in the process. Where in paper-based credentials simple physical access control often is enough, for digital credentials, access control has also to be secured digitally.

2) *Data Security*: Digital data is stored in physical storage and this storage will degenerate over time. It is, therefore, important to be able to copy the digital credential to new physical storage and to continuously monitor the quality of the storage before the degradation leads to damaged data. In libraries the "lots of copies keep stuff safe" (LOCKS) model has been successfully implemented for electronic publications, based on the idea that independent copies of the same data in physical and geographical independent data stores ensure high data security and availability [8].

3) *Data Management*: Unlike their paper-based siblings, digital credentials can only be perceived by the user if their content or metadata is rendered in a perceivable form (usually visual). Management systems need to ensure that users know what is stored and what is transmitted if requested.

TABLE I. PROPOSED RESEARCH QUESTIONS TO EVALUATE THE PERFORMANCE OF A DIGITAL EDUCATION CREDENTIAL MANAGEMENT SYSTEM IN SOLVING THE CHALLENGES EXPERIENCED BY THE USER.

Challenge	Question	Units
Fraud protection and verification	How is the system protected against fraud? What are the costs of a successful attack against the fraud protection?	qualitative time, money
Issuer dependence	What are the requirements for an issuer of digital credentials? How much does issuing a credential cost?	qualitative time, money
Handling	Describe the workflow of a credential in the system. How much does handling of a credential in the workflow cost?	qualitative time, money
Data security	How is the credential stored in the system? Is the credential data format public and open? How many independent copies of the credential are stored in the system at any time? How is the credential secured against accidental loss or data change? How is the credential secured against unauthorised, but intentional, loss or change of data?	quantitative yes/no number quantitative quantitative
Digitisation of existing credentials	How can existing analogue credentials be included into the digital workflow? Is the content of the analogue credential converted to structured data to the same level of detail as digital credentials?	quantitative yes/no
Interaction between analogue and digital workflows	How can the system interact at the same time with digital and analogue credentials How much increases the effort in the workflow, if digital and analogue credentials are mixed?	quantitative time, money
Private data protection	How is the private data stored in the system protected against unauthorised access? What are the costs of a successful attack against the private data protection?	quantitative time, money
Data management	How is the data managed from the user perspective? Can the user tell at any time of the workflow, what data exactly he/she is working with? Can the user tell at any time of the workflow, who is able to access the data in question?	quantitative yes/no yes/no
Data sovereignty	How is data sovereignty enforced in the system? Can the holder of the credential decide at any time of the workflow, who is able to access the data in question? How much does it cost the user to store the data under his/her exclusive physical access? What are the costs of a successful attack against the access protection (access, denial of service, data change)? If there are other possibilities of storage, how convenient are they to the user? What are the costs of a successful attack against these other storage possibilities (access, denial of service, data change)?	quantitative yes/no  time, money time, money time money time, money

4) *Data Sovereignty*: The ease of copying of digital data allows for the storage of digital credentials physically far from the users, for example, on the cloud. However, this also means that the actual data then is outside the physical oversight of the user. The term "data sovereignty" [9] has been coined in recent years to describe "the idea that users, being citizens or companies, have control over their data" [10].

### III. PROPOSED RESEARCH QUESTIONS

In this section, we collect the questions whose answers will be utilised to validate the effectiveness of a system devised to achieve the challenges presented in the previous Section II. Each presented topic translates into a set of questions. We start each topic with a question asking for a qualitative description of how the proposed solution approaches the relevant challenge and then, by adding quantitative questions that should enable us to measure the effect that the proposed solution has on each challenge in a given use case. Using this mixed qualitative and quantitative approach, it should be possible to compare a digital credential solution to the status quo of non-digital workflows.

In Table I, our research questions are presented; they are grouped according to the challenges presented in Section II. The challenge *data security* affects both digital and paper-based credentials in very similar ways, so we were able to combine all relevant questions into one field.

### IV. USE CASE

The EU Horizon 2020 research and innovation action QualiChain "targets the creation, piloting and evaluation of a decentralised platform for storing, sharing and verifying education and employment qualifications and focuses on the assessment of the potential of blockchain technology, algorithmic techniques and computational intelligence for disrupting the domain of public education, as well as its interfaces with private education, the labour market, public sector administrative procedures and the wider socio-economic developments." [11] The fundamental idea of the project is to build an open source, distributed platform supporting the storage, sharing and verification of education credentials. This platform will allow for the implementation of additional services which will fulfil the needs of the participating actors, such as data analytics and decision support systems. QualiChain hosts five pilot projects distributed over Europe (for details please see [12]), where the system is tested in four real-world scenarios:

- Lifelong learning;
- Smart curriculum design;
- Staffing the public sector; and
- Providing HR consultancy and competency management services

We provided online questionnaires to support the participants in the pilots in the definition of the use cases, challenges and possible research questions, as well as to define key

performance indicators. These questionnaires were filled in and discussed with the people involved in the pilots in early 2019. The process is discussed in detail in [4] and not repeated here for the sake of brevity.

## V. CONCLUSION AND FUTURE WORK

The intention of this article is to discuss the main challenges in education credential management and to present a methodology to both qualitative and quantitative measure a system's effectiveness in addressing them. Additionally, we aim at gathering feedback from the scientific community regarding these measurements and their adequacy. We apply this methodology to the use cases of the Horizon 2020 EU Project QualiChain, that cover a wide area of applications of education credentials. This will allow us an in deep evaluation of the project's performance. Based on the experience we will gather in this process, we plan to extend this work in the future to a full framework for the evaluation of the performance of education credential management solutions. This framework should be able to capture the whole life cycle of education credentials from creation and issuing over storage, management and access control, towards credential expiring or retraction.

## ACKNOWLEDGEMENT

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# Delphicare 6.0

## A Project-based Learning Approach

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**Abstract-** Sometimes, it is interesting to approach an academic laboratory class from a different perspective. This paper takes on the experience of a group of mechatronic engineering students taking an academic course on laboratory of integral electronics. The students were asked to design a system capable of measuring three vital signs of a patient. To achieve this they use the knowledge acquired in their career up to that moment or managing other knowledge that was required. In order to carry out the project, a project-based learning methodology was followed. This experience allowed the students involved to solve a real problem with a product that responded to the specifications of cost, portability and information available from a mobile device, as well as meeting the requirements to revalidate their laboratory subject matter.

**Keywords-** *project-based learning; vital signs; sensors; mobile applications.*

### I. INTRODUCTION

The realization of projects that introduce students to the solution of real-life problematics that are related to a particular subject, constitute a commonly employed method within engineering. Often referred to as the Project Based Learning (PBL) technique, it settles itself as a formal method by the end of the XIX century by William Heard Kilpatrick [1], and was renewed during the decade from 1960s as it became popular again, it has brought its recognition up to these days. In [2], PBL is defined as a methodology that enables students to obtain the required knowledge and key skills from the XXI century, through the development of projects that address and solve real life problematics. Some of the core features are:

- 1) The students being capable of becoming the protagonists of their own learning as they develop their autonomy and responsibility, since they are in charge of planning, organizing the work, and elaborating the product that attempts to overcome the established problematic.
- 2) The teacher changes their main role to a support and guidance role.
- 3) It enables users to obtain relevant and discipline-related skills, some of which are: teamwork, problem solution, responsibility, spoken and written communication, analysis and synthesis of gathered data, experiment development, socializing with external environments to college, among others [3].

Despite this method being defended by multiple authors, researchers and teachers, it is relevant to take into consideration some unfavorable elements that come with it. For instance we can mention the implementation costs, the location where the project shall be developed, the communication towards the final users who will be using the product, and finally, the time accessibility regarding the involved students due to the project being developed in parallel to the rest of the college classes. In order to implement this didactic technique, a ten-step methodology (see Table 1), was followed.

TABLE I. STEPS TO CARRY OUT PBL

Step	Short description
1	Topic selection and guide question definition. What is known already?
2	Group and role assignment
3	Defining a real product or final challenge. Setting goals and skills to reach, and the criteria to evaluate them.
4	Planification. Establishment of the job's schedule, specifying tasks, responsables for those tasks, and deadlines.
5	Investigation. Revision of previous concepts, new required concepts and information research
6	Analysis and synthesis. To share gathered information, to contribute and debate ideas, to formulate hypotheses, to structure information and to decide among team members the best solution.
7	Product elaboration. To apply the learnt design techniques (use its methodologies).
8	Presentation of the product to team members
9	Collective answering of the initial question. Following the presentation, students must ruminate in order to collectively answer the starting question.
10	Appraisal and self-appraisal. The teacher must evaluate the work in compliance with a defined rubric and propose a self-appraisal activity to the students.

Under the previously described context, this work has as its purpose, to show an experience applying PBL, same that has been in development during the period between August and December from the current year for the laboratory of integral electronics class, from the seventh semester of the mechatronic engineering career, on Tec de Monterrey, campus Laguna. As the class name implies, the course proposes the realization of 8 to 10 laboratory practices in which the students get to apply the acquired knowledge from two subjects from previous semesters: electronics and applied electronics, then, students culminate with an integrating project. For some years, this project has been



oriented to the design and construction of a domotic house, where a series of electronic devices and sensors guarantee three basic elements: comfort, security and the saving of non-renewable resources.

In this course, we came with the idea of changing the project's subject to a new one: the construction of a device that allows for the measurement of three vital signs from a person. The idea had as its background other similar works, developed by this paper's author with students from eighth and ninth semester from the mechatronic engineering career. Some questions surged out of this idea: Can a mechatronic engineering student from seventh semester accomplish this task? What knowledge doesn't the student dominate but shall apply on the design, nonetheless? Is one semester enough time for its execution? The idea was proposed at the beginning of the course to a group of 14 students, from which, 5 students felt motivated and committed to its construction. Regarding the previously exposed, the goals of the work were defined, same that are shown in Table 2.

TABLE II. GENERAL AND SPECIFIC GOALS OF THE WORK

<b>Main goal</b>	To apply the PBL approach in order to solve a real-life problem, within a class from seventh semester of mechatronic engineering.
<b>Specific goals</b>	<ol style="list-style-type: none"> <li>1. To design, mount and test a mechatronic device that allows a real time measurement of temperature, blood's oxygen and an electrocardiographic signal from a patient while it is displayed on a mobile device.</li> <li>2. To encourage the obtainment of new knowledge not seen in class.</li> <li>3. To promote teamwork among the students.</li> <li>4. Spoken and written presentation of a functional designed prototype.</li> </ol>

The paper is structured as follows: In Section 2, Methodology, it describes the approach taken to address the proposed project. In Section 3, Partial obtained results, covers the results achieved until the writing of this paper, which are not definitive as it is a work-in-progress. Finally, in Section 4 conclusions are discussed.

## II. METHODOLOGY

As it can be appreciated, part of the student's group followed the traditional final project while a group of five students would participate towards the new experience. With the latter ones a group was formed whom were exempted from making the regular laboratory practices, so they could dedicate their whole time and attention to the solution of the established challenge. Taking into consideration the methodology to apply PBL, the following stages were presented:

- 1) Starting question: Is it possible to count with a mechatronic device capable of measuring three vital signs from a person, as for it to be portable, low cost, and accessible from a mobile device?
- 2) Selection of a team leader.
- 3) The design of the rubrics to evaluate the project, and the definition of the required skills:

a) Discipline: To design, build, and test prototypes of innovative mechatronic devices.

b) Transversal: Teamwork, self-management of knowledge, and spoken and written description of the project.

4) Definition of work schedule (Table 3).

TABLE III. WORK PHASES

Phase	Action
1	Circuit board: oximeter, temperature
	Finish prototype ECG signal
	Pulse in Arduino programming
	Oximeter Thimble
	Attach the components to the thimbles
	Accommodate and couple the circuits and thimbles to the chassis
	Digital filter programming
	Couple positive and negative voltage supply
	Arduino-App communication
2	Android application
	Design and manufacture new Chassis
3	Research for the integration of new sensors
	Start with the prototypes of the new sensors

5) Analysis of required knowledge:

a) Previous: Signals analysis, electronic components, sensors, design of mechanical parts, and microcontrollers.

b) Self-studied: Development boards, mobile application development, wireless communication, sensing of oxygen presence in blood and the electrocardiographic signal.

6) This point summarizes the stages 6 and 7 of the PBL methodology, applying the general steps of the Ulrich-Eppinger mechatronic product design methodology [4].

7) At the moment of writing of this paper, phases 8, 9 and 10, from the PBL methodology, were on process.

## III. PARTIAL RESULTS

To present the results obtained so far. We will refer to stages 3 and 5 of the PBL methodology. In stage 3, it was very important to verify the acquisition of the defined disciplinary and transversal competences. Stage 5, allowed to determine what was the new knowledge that students had to manage independently.

The disciplinary competence proposed the construction, assembly and testing of a prototype enabling to measure three vital human signs: temperature, oxygen concentration in blood and a electrocardiographic signal.

The block diagram in Figure 1 recalls the process of the prototype.

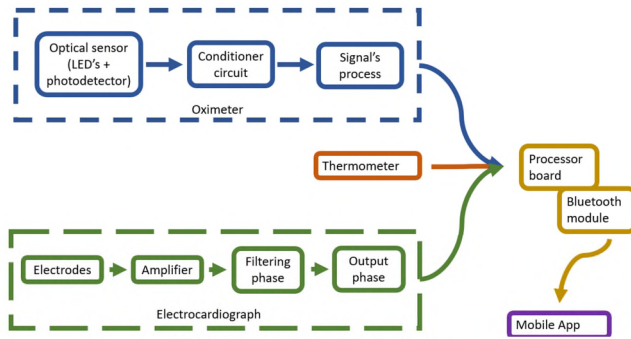


Figure 1 Delphi's. block diagram.

Next, a brief explanation is given about the implementation and obtained results, with the help of the block diagram, and gained knowledge.

#### A. Temperature Measurement

The temperature module of the system consists of the MLX90614 sensor [5], which is an infrared thermometer suitable for measuring temperatures in the necessary range between 20°C and 50 °C, with digital outputs of 17 bits. The sensor provides an output using the I2C protocol for maximum resolution (0.02°C). The sensor has a default range of temperature between -40 °C and +85 °C. The given temperature value is the average temperature of the object detected by the sensing field from the device. The accuracy of the sensor is of 0.5 °C at room temperature at 25 °C. This sensor is compatible with the analog pins of Arduino.

The temperature data obtained through the device were compared against measurements made with a thermometer, same that are shown in Table 4.

TABLE IV. WORK SCHEDULE

<i>DelphiCare</i>	<i>Thermometer</i>
37.48	37.1
37.24	37
36.94	36.8
36.7	36.6
36.52	36.5
36.3	36.2
36.14	36.5

Observe that the collected data in both cases are very similar.

#### B. Measurement of Oxygen Concentration in Blood

The oxygen sensor was designed from scratch. The SpO2 sensor (oxygen concentration in blood) [6] is based on the principle of pulse oximetry, it generates two beams of light, one of them in the red light spectrum (wavelength: 600nm-750nm) and the other in the infrared spectrum (wavelength: 850nm - 1000nm) and measures the amount of light that is transmitted through the index finger and reaches the photodetector, in this case a photodiode

connected to a current/voltage converter made out of operational amplifiers.

The oximeter is composed of three main parts: the optical sensor, the conditioning circuit, and processing board. The Table 5 shows the readings obtained by the DelphiCare's oxygen sensor, compared against a commercial sensor.

TABLE V. OXYGEN READINGS

<i>Oxygen Saturation (%SpO2)</i>	
<i>DelphiCare</i>	<i>Commercial Sensor</i>
98	98
99	98
98	98
98	99
99	99
99	99

#### C. Electrocardiograph

There is a large amount of circuits that measure the electrocardiographic signal. One of the goals of the DelphiCare was to obtain a system that was low cost and had a large portability in comparison with similar systems. Finally a circuit that obtains a signal from the heart was chosen and built. As it is shown in the block diagram in Figure 1, the signal is obtained through a series of electrodes connected to the chest of the user, after collecting said signal, it is then subjected to several amplifications and filters, so it becomes easier to be identified and to work with before reaching the analog port of the Arduino board and finally transferred to the mobile app. The resultant signal is shown in Figure 2.



Figure 2. Resultant electrocardiographic signal

#### D. Processing Board, BT Module and Mobile Application

The goal of the mobile application is to offer the user an intuitive and reliable way to communicate with the different sensors. The application is planned to perform a synchronization process with a server in order to store the incoming information in a database; the server shall display that data on a web platform for physicians to analyze. In other words, the objective of the mobile application is to serve as a bridge between the user, the sensor and the server.

The application shows a main menu where the user is prompted to choose a sensor to start a reading (Figure 3).

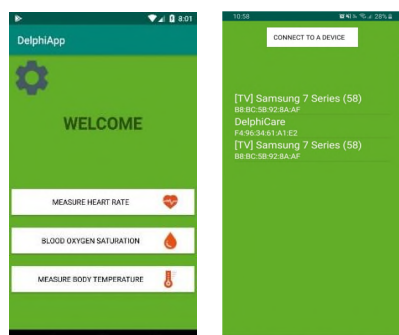


Figure 3. Mobile application menu and discovered bluetooth devices.

Before any reading is performed, the user must connect the mobile device to the DelphiCare device by means of an RFCOMM channel established via bluetooth. The application is capable of starting the connection from within, so the user does not need to minimize the application nor use the phone's built-in configuration app in order to start trading data with the sensor.

The user is able to select a device to establish a connection with, and once done, the buttons to start the measurements with any of the three integrated sensors on the DelphiCare, are enabled.

As expected, there are three main use cases: Measure heart rate, measure blood oxygen concentration, and measure body temperature. In the first case, the user will be asked to put on the electrodes on their chest and press the confirmation button in order to start the reading process. Once the measuring is finished, the user will be shown a graph with the acquired data plotted in order to achieve a proper visualization. In the second and third case, where the user can measure their oxygen saturation and body temperature, the user will be asked to insert their index finger into the corresponding finger grip and wait a couple of seconds before showcasing the results.

Currently, the application is designed to work on Android devices only, as it is still being used as a proof of concept. The Java Programming Language was selected as the technology for development is highly flexible and contrary to the most recent Android development language released, Kotlin, Java has a huge legacy, and therefore, the learning curve is very straightforward, moreover, there is an enormous amount of online resources available for research.

#### E. New knowledge management required

As expected, this project required to manage the following information:

1) Arduino UNO board. This board was studied and used, in order to take advantage of its analog ports, voltage source of 3.3V, the MLX 90614 library (used for infrared thermometers), functions for reading analog inputs, outputting and signal filtering.

2) Oxygen concentration in blood: use of optoelectronic techniques (visible and infrared light), pulse oximetry, light absorption principle (Beer-Lambert law).

3) Electrocardiographic signal: use of high gain sensors aimed to sense biomedic signals.

4) Wireless communication through a Bluetooth module.

5) Mobile app design using Android Studio and the Java Programming Language.

#### IV. CONCLUSIONS

It has been observed and reported the student's progress throughout their experience, therefore the drawn conclusions over this project are satisfactory given that they have shown how the students had experimented and accomplished the established goals using the Project-Based Learning method. As for the project itself, it is highly interesting to observe how current technology can be integrated into past technology in order to renew it and scale it towards more complex systems. The usage of mobile phones for daily and recurrent services has successfully proven to be easier and cheaper, in this case, there was no difference. This powerful tool will certainly allow for future escalation and spreading of the DelphiCare system.

As noted before, this work was submitted to be considered before completing all the phases from the PBL methodology. However, it is worth mentioning some results and information, gained through the process:

1- A prototype from a mechatronic device was implemented, allowing measurement of three vital signs of a human being, applying the PBL approach. The device is simple, portable and low cost (lower than 3000 MXN pesos).

2- Through the course of the semester, the students showed progress, which was proved by oral and written presentations, partial and final tests, which were received and evaluated with their corresponding rubric form.

3- In order to reach a solution the students had to apply the gained knowledge.

4- The project covered 80% of the program from the class, from a different didactic approach.

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# Solution for Real Problems through Research by Undergraduate Students

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**Abstract**— The present work gathers all the experience and knowledge from a group of students of last semester, taking the course entitled “Project of mechatronic engineering”, which focused on actual problems of the local region. This class used an investigation method to approach these problems and teach students about self-learning. The objective of this project was to show students how the theory learned in school can be applied on the field.

**Keywords**— *inquiry-based learning; project; challenge; image processing.*

## I. INTRODUCTION

In many situations, undergraduate students struggle to identify the relationship between the knowledge they have acquired throughout the course of their bachelor studies and their future jobs. Some manage to apply their studies through internships in their field, where they develop specific tasks for the companies they work for; others get involved in projects of interest to those entities and develop other abilities through research.

The current tendency to solve these problems is the linkage through university-industry projects that can occur through different pedagogical approaches, for example Research-Based Learning (RBL). This approach consists in applying teaching and learning strategies that aim to connect research with teaching. [1]. Berkeley, Warwick, MIT, Oxford, among others, are prestigious universities that promote this practice.

Pedaste et al. [2] identify and summarize the main characteristics of the RBL and set out the five phases and subphases, which are written in parenthesis, that distinguish it (see Figure 1): orientation, conceptualization (questioning and hypothesis generation), investigation (exploration, experimentation and data interpretation), conclusion, discussion (communication and reflection).

The authors did not find a framework which could gather and elaborate on the five phases and subphases exposed above, which allowed them to define the phases and subphases in what they called the Research Cycle, as shown in Figure 1.

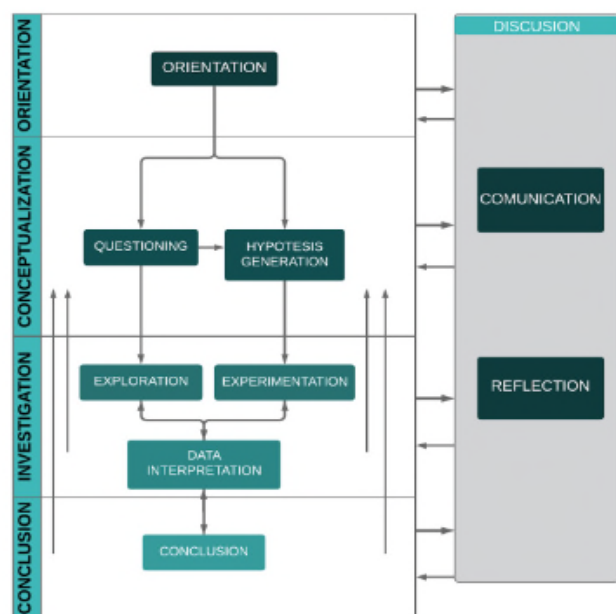


Figure 1. Research Cycle.

It is important to mention three elements of reference [2]:

1) The formulation of the technique is useful as guidance for those who desire to incorporate the pedagogical approach of RBL in their classes.

2) The presence of the discussion phase running parallel to the other phases provides a method in which designing is constantly happening, and it is not necessary to wait until the end to make adjustments because pondering and communication can be done at any moment.

3) Depending on the available information regarding the problem, three approaches can be proposed by students to develop the project: based on data, based on a hypothesis starting from a known theory, and based on questions that allow the formulation of a hypothesis. This last one is considered to come from the second.

Among the advantages that RBL offers, it can be mentioned that it allows better mentoring relationships between the professors and the students than traditional

teaching, which results in improved learning and retention in undergraduate students. Also, enrollment in postgraduate education might be increased. In addition, students develop creativity, problem solving and intellectual independence; they also develop an understanding of research methodology. Finally, RBL promotes a culture oriented towards innovation. The other pillar that supports this work is Applied Research (AR). The term “Applied Research” was popularized during the twentieth century to refer to the type of scientific studies aimed at solving problems of daily life and controlling practical situations. It is currently a relevant topic, considering the close connection it has between education and industry. Its objective is to solve a specific approach focusing on the search and consolidation of knowledge for its application and, therefore, for the enrichment of cultural and scientific development [3].

Some important considerations about AR are highlighted below:

1) It can not be developed outside of theoretical and basic knowledge, which means that it is based on the results of Basic Research (BR), so that AR is the logical continuity of BR. However, the relationship between AR and BR is biunivocal, because the results of the AR help to rectify and expand the concepts emanating from the BR, thus contributing to the consolidations of a theory. As expressed in [4], many academics carry out the hybrid research, mixing both types of research, due to the need to obtain funds for their investigation, which can be provided by public or private institutions, letting them to test or apply what they have researched.

2) It allows to transform theoretical knowledge into concepts, prototypes, products, processes or services. This implies a close collaboration between the academy and higher education (teachers and students), industry and users. Therefore, there is a need for the participation of the end users and the industry responsible for verifying that it meets the needs.

This work gathers the experience carried out by mechatronic students, which allows them to identify the relationship between the knowledge acquired throughout their career, and an application in a real work environment. Part of the objective of devolving the current research work was to answer the question: “To what extent do the mechatronic engineering students recognize the link between the knowledge acquired in their career and the way they carry out an AR project associated with the solution of a real-world problem proposed by a company or an institution?”

First, the students were presented with a need from a company or institution, which must be solved by applying the knowledge gained throughout their career. After choosing a problem, the objectives were set. Table I shows the general objective and the specific objectives set.

The structure of the paper is as follows. In Section 2, we explain the approach taken to address the work and which projects arose from class. In Section 3, the results are explained and divided between each component of the project. We conclude in Section 4 with a summary of the work.

TABLE I. GENERAL AND SPECIFIC OBJETVIES OF THE WORK.

<b>Main Goal</b>	Determine the extent to which a mechatronic engineer student can manage to identify the relation between the knowledge of their profession and the surrounding environment, by carrying out an AR project associated with the solution of a real-world problem, proposed by a company or an institution.
<b>Specific Objectives</b>	<ol style="list-style-type: none"> <li>1. Apply the RBL approach to develop AR projects</li> <li>2. Identify the characteristics of an AR from this definition and its differences with an BR.</li> <li>3. Design, build and test prototypes of mechatronic products that solve specific problems in their area of activity.</li> <li>4. Promote the management of new knowledge not addressed in classes.</li> <li>5. Encourage teamwork, so that this leads to the development of a functional mechatronic product, and to the elaboration of the descriptive memory that collects all the information corresponding to its design.</li> <li>6. Expose the results achieved before a court of professors and experts.</li> </ol>

## II. METHODOLOGY

The RBL was developed through an AR in the class of “Project of mechatronic engineering”, whose essence is precisely the solution of a real-world problem in a given context, seeking the implementation or the use of knowledge received or self-acquired. 13 students participated in this task, which were grouped into two teams at the beginning of the semester, and they had the full semester to complete the project.

TABLE II. PROBLEMS RAISED.

<b>Problem</b>	<b>Research characterization</b>
<b>Temperature measurement of stable cattle</b>	<p>Problem situation: problems with measuring the temperature of dairy cattle.</p> <p>Problem: there is no system capable of measuring in real time the temperature of a cow, which allows predicting diseases, stress or their mating season.</p> <p>Object of study: measurement of body temperature of living beings.</p> <p>Field of action: methods to measure the temperature of a dairy cow.</p> <p>Course objective: design, assemble and test a prototype system to measure the temperature of a dairy herd.</p> <p>Task: study of methods to measure body temperature; design prototypes based on image acquisition and processing acquired temperature measurements using thermal imaging cameras; make measurements with the prototype and process the data obtained.</p> <p>Hypothesis: with a system to measure in real time the body temperature of a cow, one can predict the caloric stress, symptoms of disease and the mating season of the animal.</p>
<b>Flow sensor for semi automated milking station</b>	<p>Problem Situation: Problems within the measurement of milk in a milking semi-automatic system.</p> <p>Problem: Lack of a device able to measure constantly the flow of the liquid, with a minimum error of 5%.</p> <p>Object of study: Study of the flow and measurement of fluids.</p> <p>Field of action: Methods to reduce the turbulence in flowing liquids.</p> <p>General objective: Design, mount and test a working prototype of a turbulent fluid flow sensor, with an error less than 5%.</p> <p>Tasks: Study the classical methods to reduce the turbulences on a fluid; design prototypes based on aerodynamic profiles and on the brachistochrone curve; characterize measurements using optoelectronics; measure with different prototypes and process the gained data.</p> <p>Hypothesis: Reducing the turbulence on the fluid will raise the precision and accuracy of the measurement, within a 5% error.</p>



Of the three routes suggested in [9], the second one was chosen, where from a real known problem and an idea-solution based on a theory, a hypothesis is generated. The hypothesis triggers a research process based on experiments, tests and analysis of the results. Each team worked on a different problem, which is shown in Table II.

Both problems were worked on during the time given. The students had freedom to find their own solutions, in order to encourage the development of abilities and skills not seen in class, helping them to gain knowledge in other areas.

### III. PARTIAL RESULTS OBTAINED

From the characterization discussed, the partial results obtained in the measurement of the temperature of the cattle are exemplified. Only these results will be explained in detail for conceptualization purposes.

After defining the method to use for the measurement of the temperature of the livestock, considering the economic resources, an approach was determined. The team decided to develop a prototype with cheap components, in a way in which it would show the main idea of the whole project.

#### A. Camera

Research was done in order to choose an accurate thermographic camera that fulfills the specifications of the project. After a thorough investigation, the Adafruit AMG8833 [5] was chosen, although the Flir E6 [6] is a better option technically, but it is too expensive for this project.

The AMG8833 camera complies with the needs of the project, although it has a poor accuracy of  $\pm 3^{\circ}\text{C}$ , a maximum reach of 5 meters and a field of view of  $60^{\circ}$ . Table III was created to show how different the accuracy of the AMG8833 is, compared to other types of temperature sensors. For the camera the maximum measured temperature was considered. Also, a wet simulation was done in order account for the situation when an animal becomes wet when water it is sprayed on it.

TABLE III. TEMPERATURE MEASUREMENTS

Body Part	Digital Thermometer	Distance	Laser		Camera	
			Dry	Wet	Dry	Wet
Hand	34.4°C	5 cm			34.5°C	32.75 °C
		30 cm	36.1°C	32.00°C	33.25°C	31.25 °C
Face	35.7°C	5 cm			35.25°C	
		30 cm	35.6°C	34.6°C	34°C	
Body	35.8°C	5 cm			35.75°C	33 °C
		30 cm	37.8°C	32.9°C	33°C	32.25 °C
		1 m	37.9°C	32.5°C	31.75°C	
		3 m	32.2°C	32.2°C	35.55°C	

The camera works with inter-integrated circuits (I2C) communication, which can be connected to a microcontroller. For this case an Arduino was chosen. As the Adafruit has open libraries for Arduino, it facilitates the use of this device. The sensor sends an 8x8 matrix of temperatures, which can be seen in Figure 2, where each number corresponds to a pixel of a picture.

```
-- Pixels Test --
[24.25, 23.50, 23.50, 23.50, 23.50, 23.50, 23.75, 23.00,
24.50, 24.25, 24.25, 24.50, 24.75, 24.50, 24.00, 24.50,
25.25, 25.25, 25.25, 25.00, 25.00, 24.75, 24.25, 24.25,
26.00, 26.75, 27.00, 26.75, 27.00, 25.50, 25.50, 24.00,
26.00, 28.25, 27.75, 28.00, 28.75, 28.50, 25.75, 24.50,
25.25, 27.50, 28.25, 29.25, 29.75, 28.25, 25.25, 24.25,
27.75, 27.75, 28.25, 29.25, 29.75, 28.75, 26.00, 24.50,
28.75, 26.75, 27.25, 28.75, 29.50, 26.50, 25.75, 24.75,
1]
```

Figure 2. 8x8 Matrix example.

Although the sensor does not capture an image, only temperatures, the data was processed on MATLAB to create an image, which is shown in Figure 3. Due to the small number of pixels, the array had to be converted into a larger one. For this, a method called bicubic interpolation was used to create a 32x32 image and improve the quality.

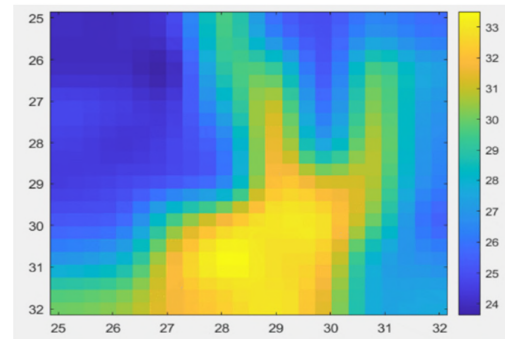


Figure 3. Thermographic image of a hand on MATLAB.

#### B. Identification System

The project is supposed to be operating in an establishment where there is a large amount of livestock. For this reason, an identification system had to be implemented, in order to identify the cow, in this case, as it gives helpful information to the carer. For identification, a radio frequency identification (RFID) RC522 module was used, but other methods can be used, such as image identification or magnetic sensor. The RFID module has a reach of approx. 5 cm [7]. Although is a short distance, these types of systems can be made so that they reach up to 10 meters, which is enough for projects implemented in the field. These systems identify pre-programmed identification cards that pass through the range of the RFID signal.

#### C. Mechanism

The location where the project would be placed is in a barn where livestock is kept. For this reason, the idea of mounting the camera with the identification system on a base, which would be held by a movement system involving a band that moves the system back and forth. It is supported by 2 rails. In addition to moving back and forth, the base of the camera can move on the spot  $120^{\circ}$  to increase the field of view. A 3D model was designed, as shown in Figure 4, before implementing it using specific materials. The materials used to create the prototype were: ABS plastic, wood, steel bars, toothed band, DC motor, servo motors, electric components (H bridge, resistors) and copper cable. The prototype range of motion was under 50 cm.



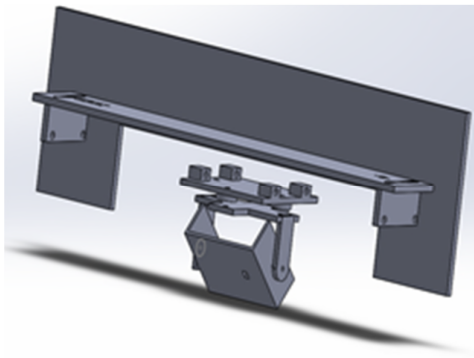


Figure 4. 3D model of the camera mount mechanism.

#### D. Data system

All the data is saved on a platform where a table of temperatures with their corresponding thermographic images is placed together with the date and time of the measurement. In this way, the end user can go back to past records or look into present ones. MATLAB was used to process the data and save such files into a specific folder in the computer.

#### E. Prototype

After consolidating all the parts of the system, the final prototype was created. An image of the result is shown in Figure 5.

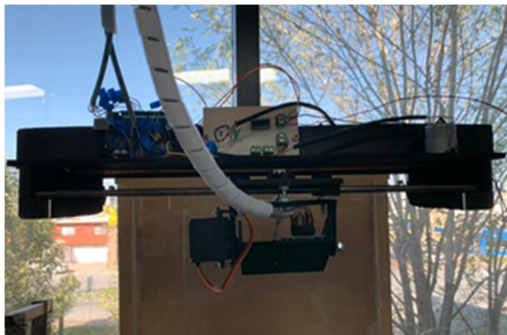


Figure 5. Final prototype of the temperature acquisition system.

As shown in Figure 5, the prototype was constructed at a smaller scale, so it can be tested in the classroom. In order to be tested in a barn, the prototype would need to measure at least 6 meters in length, to fit in the barn structure. For this reason, the team decided to first prove the mechanical and electronic functioning with a smaller size device, as a larger prototype would have the same principle.

#### IV. CONCLUSION

The objective of this paper was to allow mechatronic students to relate the acquired knowledge throughout their career, with an AR project to implement a solution for a real-world problem. This was reached through the research done and with the reported results. The RBL approach was applied throughout an entire university semester as part of the course entitled "Project of mechatronic engineering".

Following this RBL approach, solutions were reached as well as some transversal key competences were developed, for example, teamwork, written, presentation skills, and abilities to solve complex problems. In addition to

developing competences, the project's team gained knowledge regarding image processing and skills on the use of software for programming and data management, in this case were MATLAB and Arduino. The obtained results allowed the qualitative evaluation of the students (final grades between 95 and 100), two rubrics were used to grade the written proof and the oral presentation.

The project allowed students to link applied investigation with the research-based learning method, achieving something that most desire, which is to solve problem based on an industry or company needs through an academic approach.

We suggest the following recommendations for the follow-up of the project:

- 1) Employ project management tools, for example: Wrike, Asana and Flow, in order to ensure a better control of the project phases.
- 2) Apply a survey to the students, where they state what have they learned, which challenges they have overcome and what area of opportunity they discovered. In the same way, apply other survey to the client, where he can express the level of satisfaction with the problem solution.
- 3) For the complexity of the problem, the prototype was constructed at a smaller scale, which is yet to be adapted, so it can be placed in a barn.

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# Evaluating Virtual Reality as a Learning Resource: An Insight into User Experience, Usability and Learning Experience

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**Abstract**—Information and Communication Technologies (ICT) are powerful tools that support teaching and the case of Virtual Reality (VR) is especially promising because of its unique characteristics. In this paper, we report on a project that aims to describe how variables such as usability, user experience and learner interface experience might affect learning results while using VR resources. We present the preliminary results of a mixed-methods study, including the students' perceptions collected in two focus groups. These undergraduate students were exposed to the use of VR resources for learning purposes. These preliminary results invite us to think about the inclusion of different indicators to strengthen the VR resources evaluation process in higher education.

**Keywords**—Learning assessment; Learning interface experience; Usability; User experience; Virtual reality; Higher education; Educational innovation.

## I. INTRODUCTION

Information and Communication Technologies (ICT) are powerful tools to support learning because they allow students to be reached at any place and time, reducing the costs of traditional learning methods. Digital technologies provide materials for active learning that more fully engage learners [1]. The case of Virtual Reality (VR) is especially promising because of its unique characteristics. VR is a term used to describe an absorbing, interactive, computer-generated 3D virtual experience in which a person interacts in real time with simulated objects that seem real [2], and it can be used as a learning environment for different levels and disciplines [3]. Most VR environments are primarily visual experiences, but they may also include auditory simulation, which is very useful because vision provides the most information, followed by hearing; probably 90% of our world perception is visual or auditory [2]. Furthermore, the VR content can be delivered in a variety of ways, including specially made VR headsets, smartphones and computers [1]. We can group the VR systems depending on the level of immersion they offer to the user. There are different kinds of immersions that can be achieved in a virtual environment [2]:

- Tactical immersion: Experienced when performing tactile operations.
- Strategic immersion: Related to mental challenge.
- Narrative immersion: When players become invested in a story (like reading a book).
- Spatial immersion: When the simulated world is perceptually convincing (feeling of being there).
- Psychological immersion: When a player confuses the game with real life.

- Sensory immersion: Experiencing a unity of time and space (fusing with the image medium).

VR headsets (immersive system) provide the greatest sense of immersion by completely replacing the real world with the virtual one, but they are also the most expensive way to deliver it [1]. This type of system provides a stereoscopic view of the scene according to the user's position and orientation [2]. Computers (non-immersive system), on the other hand, are the simplest and most readily available method for VR playback, but they greatly reduce the sense of immersion [1]. In this case, the user views a virtual environment through one or more computer screens and is able to interact with the environment without being immersed in it [2].

The rest of the paper is structured as follows. In Section II, we present the related work. Section III presents the structure of the project, as well as the research methods and instruments used in the gathering and analysis of the preliminary data. Section IV presents the most relevant results of the two focus groups, and Section V critically analyzes the main findings and the future work to be done in this

## II. RELATED WORK

The immersion, presence and interactivity are some of the features that make VR different from other traditional media. Furthermore, the autonomy, the free navigation in a 3D space, the intuitive and realistic interaction with virtual objects and the first-person point of view are some of the VR features that contribute to a sense of presence inside the virtual environment and make the users feel as being in a real laboratory [2][3]. Mikropoulos and Bellou [3] found that all these VR features play an important role for knowledge construction, and presence is the principal feature that contributes to positive learning outcomes. Thus, these features should be taken into consideration when designing virtual environments, in combination with the discipline and specific content under study. VR implementation is mainly found in high school, college and university; with healthcare and engineering being the most investigated subject areas, followed by computer sciences, culture, history and automotive. In addition, professional education domains are now incorporating VR technologies to train their employees [4].

The implementation of VR in education is based on constructivism, which emphasizes the dynamic aspect of learning. Experiential learning is constructivist, and it emphasizes the central role that experience plays in the learning process [5]. Unlike passive information transference methods (such as lectures), VR experiences allow the learner

to control the pace of the process and make decisions that influence the outcome, making a virtual world feel real and increasing memory retention [1]. When the learning process involves learners' emotions and social life, they can better master the knowledge. Using VR allows learners to gain information from an experience that is not easily accessible or does not exist in real life, and encourages them to use their imagination when manipulating the environment, which eases the active construction of models and the skills development [2][6]. Also, creative learning and the ability to innovate can be stimulated and improved. Another advantage is that there is no risk in virtual training, learners can practice repeatedly until they master a skill [6]. For example, Tsai [7] found that using VR during training could reduce the anxiety caused by emergencies. In short, immersion in a virtual world allows us to construct knowledge from direct experience, not from descriptions of experience [8].

Durrani and Pita [4] found that VR has a very positive effect on learning. 92% of the studies they analyzed showed a positive impact of integrating VR, and the other 8% of the studies showed a neutral effect. In line with this, Marks [9] found that the exploration of a 3D model really helped students to understand the spatial structure. In addition, the VR application promoted discussions among the students and, when compared with the group using traditional materials, they showed a higher cooperation. Moreover, the VR group showed the most significant difference in the question about stimulating interest in the topic. This is where VR seems to show more promise [9]. Hence, VR can enhance the learning process, but it is not appropriate for every instructional objective or learning content. Therefore, to decide if using VR is the best option, it is necessary to evaluate the type of contents that will be taught and identify the experiences that would be difficult, dangerous or impossible to provide in formal education. Strategic and descriptive knowledge can often achieve good results without using a virtual experience. Furthermore, it is crucial to consider if creating a simulated environment is relevant to the learning objective [6][10]. Creating a pedagogical foundation when designing VR modules is an important step in their development. This process requires script writing and expert content evaluation before the modules can be recorded. Students may benefit greatly if provided with safe and effective experiential learning opportunities through VR [1].

Besides the pedagogical foundation, the application of VR technology to education requires students to be autonomous learners and to have learning initiative. This learning way is student-centered, emphasizing that students need to demonstrate their enthusiasm and initiative in the learning process [6]. However, it is important to consider that a purely exploratory tool, such as a VR application, is not sufficient to guide the students through the whole learning process. Marks [9] discovered that even though the 3D model they used in the VR tool presented all the necessary information, not all of it was discovered or remembered correctly by the students. Therefore, teachers should not think that using VR can be enough for students to finish learning. On the contrary, the use of VR in education has high requirements for teachers, who play a guiding role in the entire process and must constantly improve themselves and adapt to the needs of future teaching [6]. It is also helpful to have some guidance in the VR

application besides previous oral indications delivered by teachers, such as a list of items to work through or an audio or textual narrative. Regarding this, the majority of the participants in Marks' [9] study requested a guidance mechanism for the exploration process and short comprehension tests of the content before unlocking the next part of the tour. In conclusion, VR is a promising tool for educators, presenting important advantages like the ease of use, the increased motivation and the non-symbolic, first-person experience. However, to maximize the benefits, it is important to consider the whole context of the education process in the design of any VR application [8][9] as well as the instructional decisions teachers take to insert this kind of material for learning purposes.

As mentioned previously, many authors have evaluated the usability of VR technology [9] and the students' experience when using it as a learning tool [11], but there is very little research on its instructional usability, which is the degree in which the tool is really motivating and helping students to achieve the learning objective. In this sense, the objective of this paper is constructing an evaluation process for VR resources that considers all the aspects of the learning process.

### III. METHODOLOGY

#### A. Design

This is a mixed-methods study [11]. The objective is to describe how variables such as usability, user experience and learner interface experience might affect learning results while using VR resources.

#### B. Context and participants

This study took place in a private university located in northeastern Mexico. Undergraduate students from different programs such as engineering, medicine and business were exposed to the use of VR resources for learning purposes. The results presented in this paper focus on a VR resource that was designed to collect, calculate and estimate data from a daily activity: going to buy groceries at a supermarket. This VR tool attempted to achieve spatial immersion (a simulated world that is perceptually convincing).

In sum, 268 students from engineering and business that were taking the course "Mathematics and Data Science" used the VR tool in Monterrey; 76 students were studying at the campus in a presence-based modality and the rest were online students. The students used the VR tool for about an hour and, during this time, they had to choose 5 foods, trying to get the smallest number of calories possible. The objective of the VR tool was to help students to calculate their caloric intake and stimulate their interest in the nutritional value of the food they choose.

#### C. Instruments

Two instruments were adapted for responding to research questions: The first instrument was a questionnaire with 21 items using Likert scale (1= completely disagree, 2= disagree, 3=somewhat disagree, 4=somewhat agree, 5= agree, and 6= completely agree) divided into two sections: usability and user experience statements [9][12]–[15]. The quantitative results obtained from this questionnaire will be presented in future

work. The second instrument was a mixed questionnaire [9], [12]–[16]. In this case, this instrument was applied in a focus group technique. The instrument was divided into four sections.

- Section 1: contains 6 items about usability and 5 items about user experience. All of them are open-ended questions.
- Section 2: contains 12 items related to instructional issues and learning experience. These items use a six-point Likert scale (1= little 6= a lot), open-ended questions and statements that need to be qualified according to a scale in consensus.
- Section 3: Contains one open-ended question to make a global appreciation of students' perception of the learning experience using VR and how to improve it.
- Section 4: Contains a single-word multiple choice question that asks to select the word that best represents how they felt about the learning experience with VR. There are eight possible options that go from positive to negative emotions or feelings. A mode value is obtained after voting.

Five educational experts in tertiary education and educational technology usage made a first validation procedure for both instruments before application.

#### D. Procedures

At the time this contribution has been written, we had some partial results, as this research project is still in progress. Thus, two focus groups were formed. 13 students were randomly chosen to participate in the two focus groups. The application of the questionnaire using Likert scale is still open for collecting data and two other focus groups are pending.

The steps corresponding to the methodology procedures of this study are the following:

- Design of the instruments.
- Validation of each instrument by experts.
- Adjustment of the instruments according to expert's opinion and suggestions.
- Application of the questionnaire using an electronic format for collecting data.
- Application of focus group, with the participation of at least 7 students in each one.
- Transcription of focus group dialogues using the Amberscript online service.
- Ensure transcription in verbatim format corresponding to the content of each audio files.
- Analysis of data using IBM SPSS and ATLAS.ti software respectively.

#### IV. RESULTS

The preliminary qualitative results of the study are presented in this section. The expected and emergent categories are presented, along with the most representative students' comments, which invite us to think about the inclusion of different indicators to strengthen the evaluation process of these resources, considering three dimensions: usability, user experience and learning experience.

**Usability:** The majority of the students said that adapting to the VR was a trial and error process because people guiding them could not know for sure what they were going to do; but they felt this adaptation process was pretty fast; they agreed that the interface was very simple and easy to use. Even though the interface was perceived as very simple, students agreed they needed someone to tell them how to use it, and some of them faced some issues at the beginning and at the end of the activity and needed further instructions. They mentioned the end of the activity was confusing because it was not well defined. Students who saw their classmates do the activity first or had previous experience using VR technology were more comfortable with the environment from the beginning, but all of them would have preferred to have more instructions included directly in the VR.

With respect to the complexity of the environment, the students mentioned it was comfortable and practical. Some students perceived this simple interface as an advantage. They said supermarkets are a lot bigger compared to the one in the VR, so, this simplified things for people that do not know how to use it because they could easily reach and count everything. However, other students perceived this simplicity as a disadvantage because they felt it limited their options or made it less realistic.

**User experience:** Students agreed that it was an attractive experience that excited them. They were glad to have the opportunity to do something new and go out of the regular classroom activities. Some of them said the VR exceeded their expectations and they never imagined being able to have something like this in a class. They felt having VR tools is an advantage and the school should invest more in this technology. A few students said they even took some extra time after finishing the activity to explore the environment.

Regarding immersion, students said they were not conscious of what was happening around them, just the VR, so they felt they were the character they were controlling. They liked the 360 degrees view because they could turn their head anywhere, which made them feel immersed in the environment. The students also mentioned it was important not being told what to do, in order to feel free to experiment in the environment; they liked to have a feeling of control.

One of the issues that affected their sense of presence was that they could not find everything they were looking for, which made the experience less real. Also, they mentioned they would have felt more immersed if they had been able to walk and listen to the kind of music you find in a supermarket. Not being able to walk also made some students feel dizzy after the experience. Furthermore, they mentioned that the quality of the graphics is a key element to experience inside the game; as well as being able to do all the normal activities one can do in the real environment and interacting with the objects in a natural way, like placing the products in a shopping cart and paying for them at the cashier, in this case.

**Learning experience:** In general, students thought that using VR is a good way to learn because it takes them out of their routine. They also thought the learning objective was clear, the activity was related to their class and the VR complexity was adequate for the purpose of the activity. About the effort they had to do to learn, they said they did not have to focus a lot because the objective was clear, they were familiar with the context and they were comfortable with the

use of technology. They added that the mental effort would have been a lot greater if they had not had any instructions. In relation to the physical effort, they said no effort is needed and anyone can do it, even a person with a physical impairment can enjoy it.

Although students thought the VR experience was related to their class, the majority expected a more analytic experience, in which they could see graphics and interpret information. Considering this, the majority of the students agreed this experience is more relevant as an introductory activity, to learn a new concept, rather than a practice. In addition, they thought having more products in the supermarket would have also enhanced their learning experience because they would have been able to analyze more data. They also emphasized having the right calorie values is important in order to use those values in their analysis.

With respect to the time they had for the learning experience, students in the two groups had different opinions. In one of the groups there were more students, so they felt they did not have enough time to interact with the VR tool. The other group had very few students and they felt they had a lot of time for the activity, they even mentioned the activity should have a limited amount of time in order to be more like a game and compete with their classmates. In addition to the competition, students also mentioned they would like this tool to allow a more social learning. They said they would like to have more people connected in the same virtual environment, including the teacher.

Students concluded this tool should be used in more subjects at the university, and they should be able to use it more frequently. They even mentioned they would be able to learn more and benefit more from the tool if they could access it at any time, using it as a reference material. Students say they can not really learn anything if they only use the tool once.

Table 1 summarizes the most relevant students' comments for each dimension.

TABLE I. STUDENTS' PERCEPTIONS

Dimensions	Students' comments	
	Features appreciated in the VR	Missing features in the VR
Usability	"I adapted very fast, it was really easy to use and simple" "I had seen others do it, so it was easier" "I feel that if more things are added, people who don't know how to use the VR will start to get confused"	"If there had not been a professor explaining everything, I wouldn't have known what to do" "I finished and I did not know what to do next" "The game does not have a lot of food options, so it is easy to repeat other's actions"
User experience	"I really liked the experience, and when I finished, I wandered around to see the products" "It is a new experience for many of us and you go out of the classroom, because it is very tedious to be in the classroom all the time"	"I could not find meat, chicken or something more similar to what I really eat" "I would have preferred to walk instead of teleporting" "The music of a normal supermarket, or hearing people talking would have"

Dimensions	Students' comments	
	Features appreciated in the VR	Missing features in the VR
	"What made me feel immersed is the fact I could turn my head anywhere freely, see everything, and move anywhere I wanted to"	"made me feel inside a supermarket" "To be like a supermarket, we should have been able to pay for the products, having a shopping cart and going to the cash register"
Learning experience	"The program was simple, but we did not need a lot more detail for the learning objective we had" "It meets the objective and it's very simple" "The way to use it was so simple and clear that it did not require a lot of mental effort to understand what you were doing, maybe you need a little bit more effort to apply it in class"	"We understood the data collection, but not its analysis, which is the focus of the course" "I would prefer to have this activity starting the semester and build on this experience to do further activities" "I did not like to feel pressured by the time" "I would like it to be more competitive" "I imagine having a digital class with everyone connected; like an interactive classroom" "We should be able to access the resource freely"

This preliminary qualitative analysis allows us to rethink about the indicators that should be considered to evaluate a VR didactic resource for learning processes in higher education.

## V. CONCLUSION AND FUTURE WORK

These preliminary results seem to confirm that the features proposed by Mikropoulos and Bellou [3] strongly contribute to a sense of presence when using a VR tool. Students agreed that the free navigation, the autonomy, the 360 degrees view and the interaction with the objects made their experience more realistic. They also mentioned they would have appreciated involving more senses in the experience, for example listening to the type of music they would hear if they were really in the place.

However, VR tools should be used carefully because they are not appropriate for every instructional objective. The students in this study said that they would have preferred to have this experience at the beginning of the semester and build on it for further activities. In addition, they felt that the resource objective was limited; they would have appreciated analyzing the data they collected during the experience. This supports Pantelidis [10] suggestions about creating a pedagogical foundation when designing VR modules; the interaction with 3D objects by itself will not be enough to achieve better learning outcomes.

Furthermore, this study corroborated that teachers play an essential role when using this technology [6]. Teachers should clarify the learning objective of the resource before using it, and they should also define the steps students should follow and what is expected from them. After the experience, it is also important for teachers to engage students into a discussion about what they learned and how they can apply it to further class activities and to their daily life.

This study presents qualitative preliminary results, but the three dimensions will be evaluated using quantitative data, and interviews with teachers will be done. VR resources have demonstrated to have a great potential to enhance the learning process, but we must carefully define the learning objective and guide the students' experience. It is important to continue evaluating the characteristics that must be considered when using VR tools in higher education.

In this respect, future work must consider students' characteristics, analyzing any differences in the VR experience related to their gender, the program they are studying, their previous experience using VR, and their learning styles. In order to generalize results, it is important to include larger samples of students in different disciplines and with different characteristics. This could also allow measuring other variables such as acceptability of VR tools and user satisfaction.

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